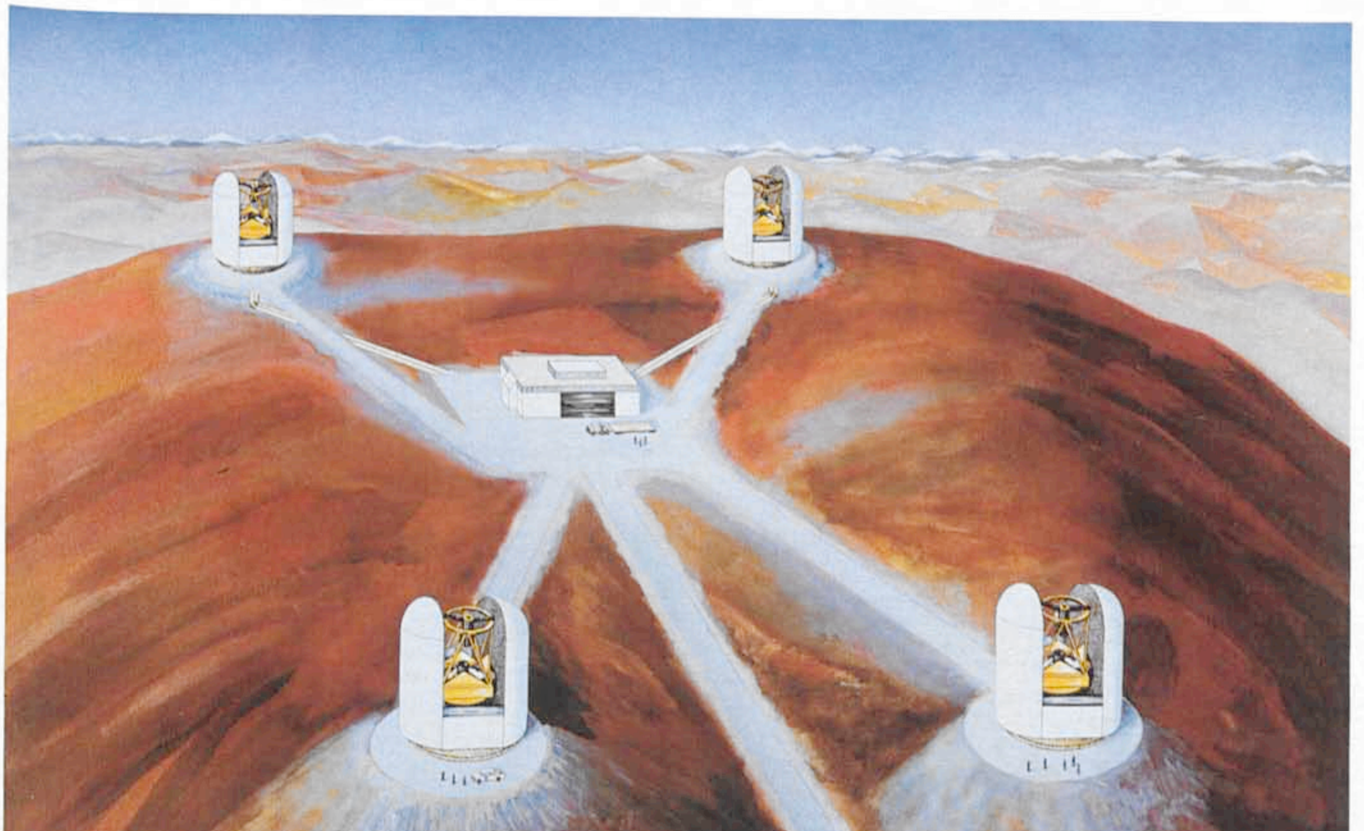
THE MESSENGER

EL MENSAJERO

No. 34 – December 1983

The Very Large Telescope Project

D. Enard, Head of the VLT Project Group, and
J.-P. Swings, Chairman of the VLT Astronomy Advisory Committee



Artist's view of an early ESO VLT concept, representing a array of four 8 metre telescopes, of which two are shown to be linked for interferometric capabilities. It now seems preferable to do interferometry by adding to the large dishes a few smaller size (2–3 metre) telescopes that would be movable. (Drawing by J.-M. Leclercqz.)

As emphasized unanimously at the time of the Cargèse workshop[1], a Very Large Telescope (VLT) project is of vital importance to the future vigour of European astronomy. The table given below shows indeed that "competing" projects exist in the US, UK, USSR, all of which are to be completed within about 10 years. The Space Telescope is indicated in the same table for comparison, in order to stress its high cost and its size of "only" 2.4 metres. It is also very important to keep in mind that the Space Telescope and future large ground-based telescopes are to be considered as complementary, not as competitors.

The area of very large telescopes is in continuous development and progress: five international conferences have indeed been devoted to the subject since 1977, the last one in September 1983. The next one will be the IAU Colloquium 79 on "Very Large Telescopes, their Instrumentation and Programs", to be held in ESO (Garching) in April 1984.

Scientific objectives for VLTs have been listed on several occasions: a number of them may, for example, be found in the Proceedings of the Cargèse Workshop[1]; only a few will be mentioned hereafter. In all cases, it turns out that the main use of a VLT will be in the areas of spectroscopy and of high spatial resolution imaging.

The high light gathering power of a VLT will make possible a whole range of observations which at present cannot be made at all or only in a very limited way: they concern primarily low-resolution spectroscopy of very faint objects as well as high-resolution spectroscopy of a wide variety of objects with intermediate brightness. Targets will undoubtedly cover a tremendous range of distances, from solar system sources to objects at the edge of the universe. For illustration, let us simply mention a few tantalizing possibilities:

- Spectroscopic observations of the outer planets and cometary nuclei to search for various molecules with low abundances;
- High spectral resolution observations leading to detailed abundances of elements in stars in different parts of our galaxy, the Magellanic Clouds and other satellite galaxies, which would give essential information on the origin of the elements;
- Stellar seismology: the observation of oscillations like those found on the Sun, which give much information on the stellar internal constitution and rotation;
- High time resolution photometric, spectroscopic and polarimetric observations of compact X-ray sources which may contain black holes, of X-ray burst sources, of dwarf novae and other rapidly varying objects;
- Spectroscopy in the IR of quasars and active galaxies to determine the internal absorption and to study the kinematics of the absorbed region;
- High spectral resolution observations of quasar narrow absorption lines and the consequent mapping of the distribution of intergalactic matter in the universe;
- Spectroscopic observations of very distant galaxies to study their evolution, and from this to gain further information on the expansion of the universe.

High resolution imaging is perhaps one of the most fascinating capabilities of ESO's future VLT: speckle techniques, as well as direct imaging, especially in the infrared where the diffraction limit of the telescope is achieved, would become possible down to extremely faint objects. In areas such as the infrared again, advantage could immediately be taken of the two-dimensional arrays that are presently being developed. This would enable morphological studies of objects ranging all the way from asteroids to galactic nuclei, and perhaps permit the detection of "solar systems" in their early phase of formation.

What is the best way of making these observations possible with the highest efficiency? A study group within ESO has looked into this problem while considering the three following possibilities:

(a) A single dish of 16 m diameter with a segmented mirror;
(b) A multimirror telescope (MMT) with, for example, four 8 m monolithic mirrors;
(c) An array of independent telescopes – for example four 8 m telescopes.

The first option (a) suffers from two basic problems: a very sophisticated and as yet untried control system will be needed to keep the segments aligned to optical specifications, and the long focal length makes it very difficult to construct efficient matching spectrographs. The main advantage of this option would be that in the IR and for optical speckle work the largest possible aperture is desirable. The second option (b) alleviates the spectrographic matching problems, while the extension of conventional mirror technology to 8 metres seems achievable. In principle, it is possible to combine the light from the different mirrors optically, but the additional loss of light makes this less attractive in many applications. The third option (c) is very similar, except that with independent telescopes more flexibility is obtained; furthermore in this configuration, interesting possibilities may exist for interferometry.

An additional element to be considered for the selection of the concept is the technology available to make the primary mirror. Extensive research is currently being carried out at ESO for the New Technology Telescope (NTT) project on the active control of a thin ("deformable") dish. It seems, on the basis of the experience that has been gained that a large, actively

[1] Workshop on ESO's Very Large Telescope, Cargèse 16–19 May, 1983; ESO Conference and Workshop Proceedings No. 17; eds. J.-P. Swings and K. Kjär.

PROJECT	SIZE OR EQUIVALENT DIAMETER	PRESENT COST ESTIMATE (approx.)	CHARACTERISTICS	LOCATION
University of Texas	7.6 m	40 M $	very thin monolith	Davis Mts., Texas
University of California	10 m	50 M $	segmented primary	Mauna Kea, Hawaii
US National New Technology Telescope (NNTT)	15 m	100 M $	segmented primary or multiple mirror	Mauna Kea or Mt. Graham (Arizona)
USSR	25 m	?	segmented primary	?
ESO (VLT)	16 m	270 M DM	array + interferometer?	Chile?
Space Telescope (ST)	2.4 m	1,200 M $	use: 85% US; 15% Europe	launch 1986

Note: It should also be mentioned that large telescope projects (e.g. 17.6 m multi-mirror, very large Schmidt) are presently under study in the United Kingdom.

corrected monolithic mirror would be a reasonable choice for the VLT. At the time of the NTT completion which might also correspond to the start of the construction of the VLT, enough experience will have been acquired (including tests on a real telescope) so that the extrapolation of the NTT technology up to a diameter of about 8–10 m will be possible. The corresponding blank will not necessarily be a solid meniscus but will more likely be a hollow honeycomb structure either made out of glass or metal. There too, the important investigation on metal mirrors carried out in the framework of the NTT project may have an important impact on the VLT.

As a result of these various considerations, option (c) seems at the moment the most attractive. A similar conclusion was also reached by ESO's Scientific and Technical Committee at its meeting on 8 November, 1983, where it was clearly recommended that ESO should consider its VLT as a limited array of large telescopes, and start as soon as possible on the definition of the first of its 8–10 metre elements.

Interferometry is only meaningful if some of the telescopes are mobile. Again, the cost aspects of making a telescope mobile but at the same time stable to high accuracy, need be studied. Alternatively, at least in the IR it may be profitable to do interferometry with a combination of fixed 8 m and mobile smaller telescopes. This point also needs further study.

Another set of studies which started a few months ago is that related to the choice of a site for the VLT. The absolute requirement for the site for an expensive telescope to be operated at its highest efficiency is excellent seeing. This is already the case when only standard applications like various types of spectroscopy, or faint object observation, or infrared photometry are considered. It is still more strongly the case in interferometric applications where the signal-to-noise ratio may vary with as much as the 3rd or 4th power of the seeing parameter. A second and important requirement is very low humidity for IR studies; regions with strong winds are also to be avoided.

One should also note that the selection of a site is not without consequence for the definition of the concept. For instance it may not be obvious to find an excellent site on which both a coherent long baseline array and the large telescopes can fit together without affecting the performance of one or the other.

A workshop on "Site Testing for Future Large Telescopes" was held very recently (Oct. 4–6) at ESO in Chile in order to "review what is being done to test and compare the very best sites in the world and what more should be done in the coming few years". Meteorological observations and measurements of total precipitable water content have already been started in a few very dry sites in northern Chile. Seeing studies should be taken up next year if these first measurements are satisfactory.

Together with the measurements for site selection, technical studies are being initiated, as well as a detailed discussion of the implications on the scientific objectives. Suggestions and research proposals from institutes in the ESO countries on subjects related to the VLT (either on concepts, technology, instrumentation, or in more specific areas such as wide band high efficiency coatings, image slicers, fiber optics . . .) will be sollicited.

A New Class of Cataclysmic Variables: the Intermediate Polars

M. Mouchet, Observatoire de Meudon

Introduction

Several newly discovered hard X-ray sources (kT > 2 keV) were identified with binary systems, characterized by an orbital period of 3 to 4 hours and by strong emission lines in the optical and ultraviolet superimposed on a blue continuum. (Fig. 1, 2). Moreover, these systems exhibit strong periodic and coherent variations on a time scale of ten minutes, the so-called "pulsations", with a full amplitude from 10 to 40%. (Fig. 3). These

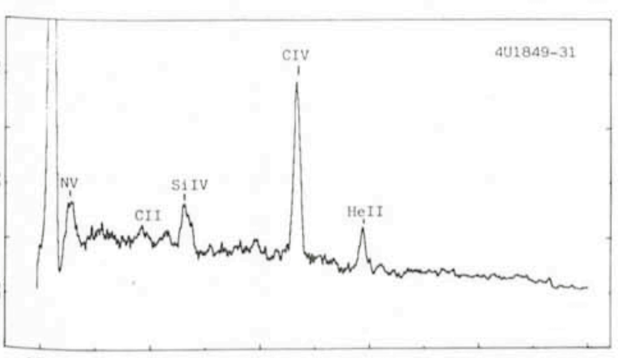


Fig. 1: *Average IUE spectrum of 4U1849–31.*

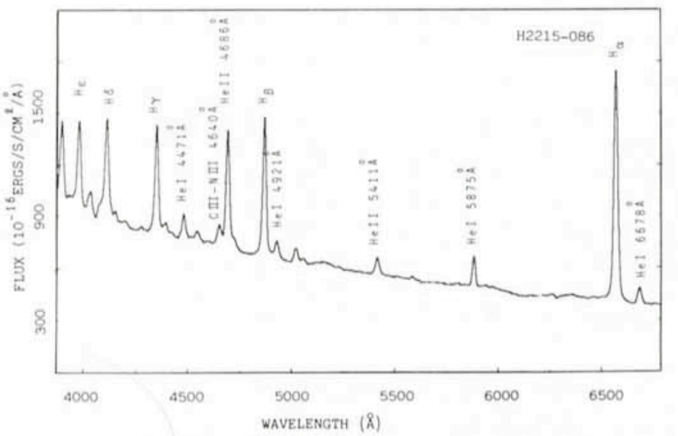


Fig. 2: *Average optical spectrum of H2215–086 obtained at the 3.6 m telescope using the IDS attached at the Boller and Chivens spectrograph. Note the strong He II 4686 Å line.*

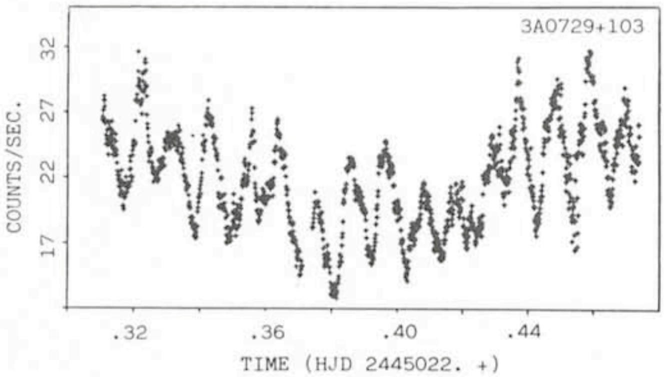


Fig. 3: *Light-curve of 3A0729+103. Strong pulsations with a 15.2-min period are observed. (Warner, B., 1983, IAU Colloquium No. 72, p. 155, reproduced with the author's permission).*

sources are related to the class of cataclysmic variables: close binaries in which a red dwarf secondary fills its Roche lobe and transfers matter via an accretion disk onto the surface of a white dwarf (see Ritter, H., 1980, *The Messenger* No. 21). The novae and the dwarf novae are well-known members of this class. Some results concerning individual objects of these types are presented in several articles published in the *Messenger* (Drechsel, H. et al., 1983, No. 32; Stolz, B., 1981, No. 26; Drechsel, H. et al., 1980, No. 22; . . .). The peculiar sources discussed here are called "intermediate polars". The origin of this name will be justified in a following paragraph. Optical outbursts similar to those observed in novae or in dwarf novae have not yet been recorded in intermediate polars, besides low states (1 to 3 magnitudes below the usual value) that have been discovered in two sources from the Harvard plate collection.

Up to now four objects of this new class have been discovered, showing optical pulsations. Two of them also exhibit X-ray pulsations with similar periods (Table 1). A detailed study of H2252-035 and 4U1849-31 has revealed the presence of two nearby periods in the optical pulsations, so that their beat period corresponds to the orbital one.

Table 1. Periods observed in intermediate polars

Source	Orbital period	Pulsation periods Optical	X-ray
H2252-035 (AO Pisc)	3.59 h	14.2 min 13.4 min	13.4 min
4U1849-31 (V1223-Sgr)	3.36 h	13.2 min 14.2 min	?
H2215-086	4.03 h	20.9 min 19 or 23 min ?	?
3 AO729+103	3.75 h	15.2 min	15 – 17 min

In the following paragraphs I shall give an interpretation for these pulsations, discuss the existence of an accretion disk and an accretion column and describe one of these objects, H2215-086, in more detail. A review of the properties of the intermediate polars is given by Warner (1983, IAU Colloquium No. 72, p. 155, and 1983, Proceedings of "Cataclysmic Variables and low mass X-ray Binaries", Cambridge, Mass., in press) and by Mouchet (1983, IAU Colloquium No. 72, p. 173).

The Oblique Magnetized Rotator Model

X-ray Pulsations

The pulsations described above are similar to those detected in other X-ray binaries in which the compact accreting star is a neutron star, like Cen X-3, 4U1626–37 . . . (Ilovaisky et al., 1978, *The Messenger,* No. 14). The current model for these sources consists of a magnetized compact object with a magnetic axis non aligned with the rotational one. The accreting matter is channelled along the magnetic field, and the released gravitational energy of the inflowing matter, radiated in X-rays, leads to an anisotropic X-ray emission modulated with the rotational period of the compact star (like the beam of a lighthouse). This model was proposed to explain the pulsations observed in the intermediate polars, based on the fact that they are present in X-rays for, at least, two objects.

Optical Pulsations

The X-ray pulsations find a direct explanation with the model described above. But, what about the optical pulsations? A detailed observational study of the two sources H2252–035 and 4U1849–31 could give clues for their origin. (Motch, C., and Pakull, M., 1981, *Astronomy and Astrophysics* **101,** L9, Van Paradijs, J. et al., 1983, Proceedings of "Cataclysmic Variables and low-mass X-ray Binaries", Cambridge, Mass., in press). Fast photometry of these objects was carried out at the 90 cm Dutch telescope using the Walraven photometer which allows to measure the flux simultaneously in five pass-bands ranging from 3200 Å to 5500 Å and then to evaluate the energy distribution of the two optical pulsations present in these systems. For H2252–035, the pulsation at the shortest period exhibits a steeper distribution ($F_\lambda \sim \lambda^{-4.5}$) than the 14.2 minutes pulsation ($F_\lambda \sim \lambda^{-3.3}$). Both pulsations in 4U1849–31 have the same behaviour, similar to the 14.2 minutes pulsations of H2252–035. On the basis of these results, it was possible to suggest an explanation for the optical pulsations: the steepest one observed in H2252–035 would be due to a hot spot associated to the polar cap on the white dwarf while the other kind of pulsations show an energy distribution similar to the one expected from an X-ray heated region. If the reprocessing of

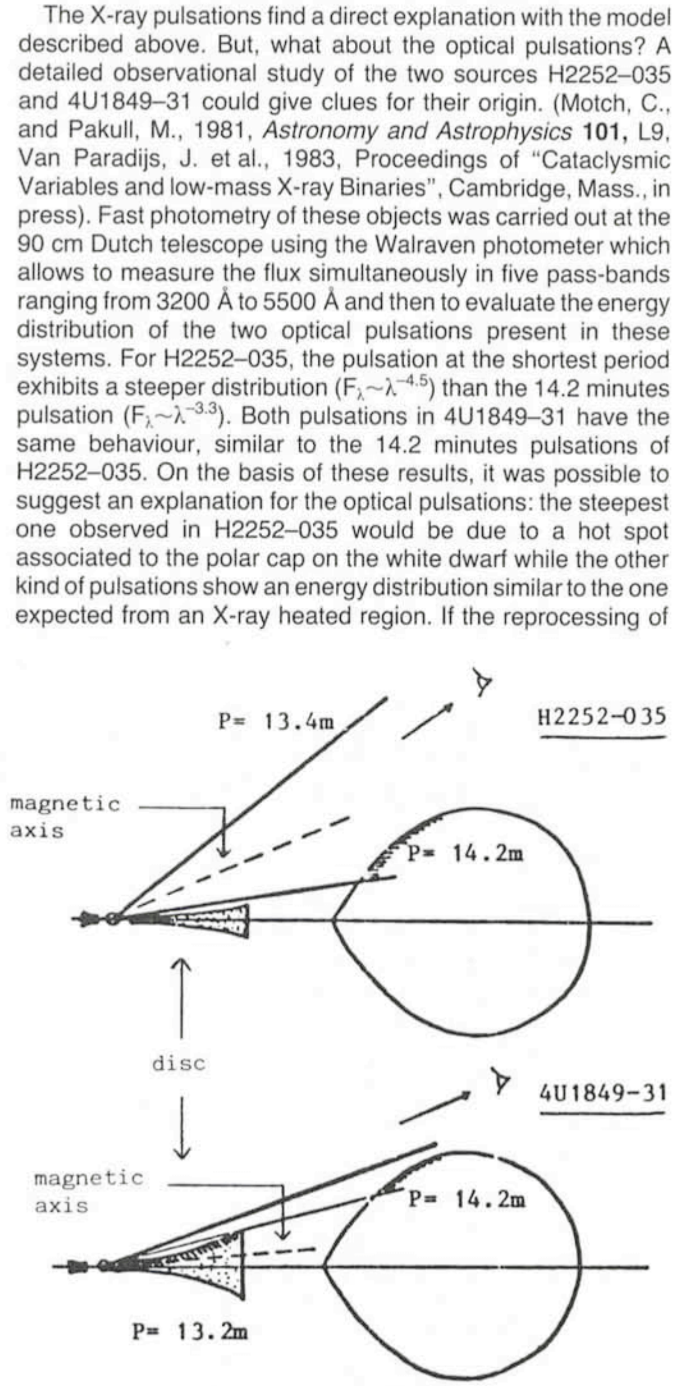


Fig. 4: *Geometrical model explaining the pulsations in H2252–035 and 4U1849–31. The hatched parts correspond to the X-ray illuminated regions. (By permission of the author: B. Warner, Proceedings of "Cataclysmic Variables and Low Mass X-ray Binaries", Cambridge, Mass., 1983, in press.)*

the X-rays occurs on an axisymmetric region (relatively to the rotational axis), the disk, for instance, the period of the optical pulsations is equal to the rotational one, while if the illuminated region is fixed in a frame rotating with the orbital period (like the secondary hemisphere or a bulge on the disk) the observed period is the beat period between the rotational and the orbital ones. Since the observed beat periods are greater than the rotational ones for both sources, the white dwarf motion is retrograde. Fig. 4, from Warner (1983), summarizes this rather long but simple explanation. Moreover this geometrical model accounts for other observational facts such as the phasing of both the pulsations and the temporary disappearance of the 14.2 min. pulsation in 4U1849–31 (from time to time the outer region of the disk intercepts the whole low inclination magnetic beam). Of course, for 4U1849–31, the discovery of an X-ray periodicity at 13.2 min would be a strong support for this explanation. A similar study of the two other sources must be done as soon as possible. For H2215–086, a first attempt of such an interpretation was done from spectroscopic data.

Clues for a Disk or an Accretion Column?

In high-inclination cataclysmic systems the existence of an accretion disk is revealed by the presence of eclipses and emission lines showing double-peaked profiles characterizing a rotational disk. These features are not observed in any of the objects discussed here for which the inclination angle is probably too low. Nevertheless it is possible to detect a disk by comparing the energy distribution of the continuum with accretion disk models. The simplest one is the optically thick disk model in which each annulus radiates the local gravitational energy as a black-body emission of temperature decreasing towards the outer parts. (For more details, see Bath et al., 1980, *Monthly Notices of the Royal Astronomical Society*, **190**, 185). It is possible to explain the energy distribution from UV to infrared with such a disk for H2252–035 and 4U1849–31, but this requires a rather extended disk and a high accretion rate. This last parameter leads to an X-ray luminosity largely higher than the observed one. This discrepancy remains even if other contributions are considered (the reprocessed X-ray flux, the white dwarf, the secondary . . .)

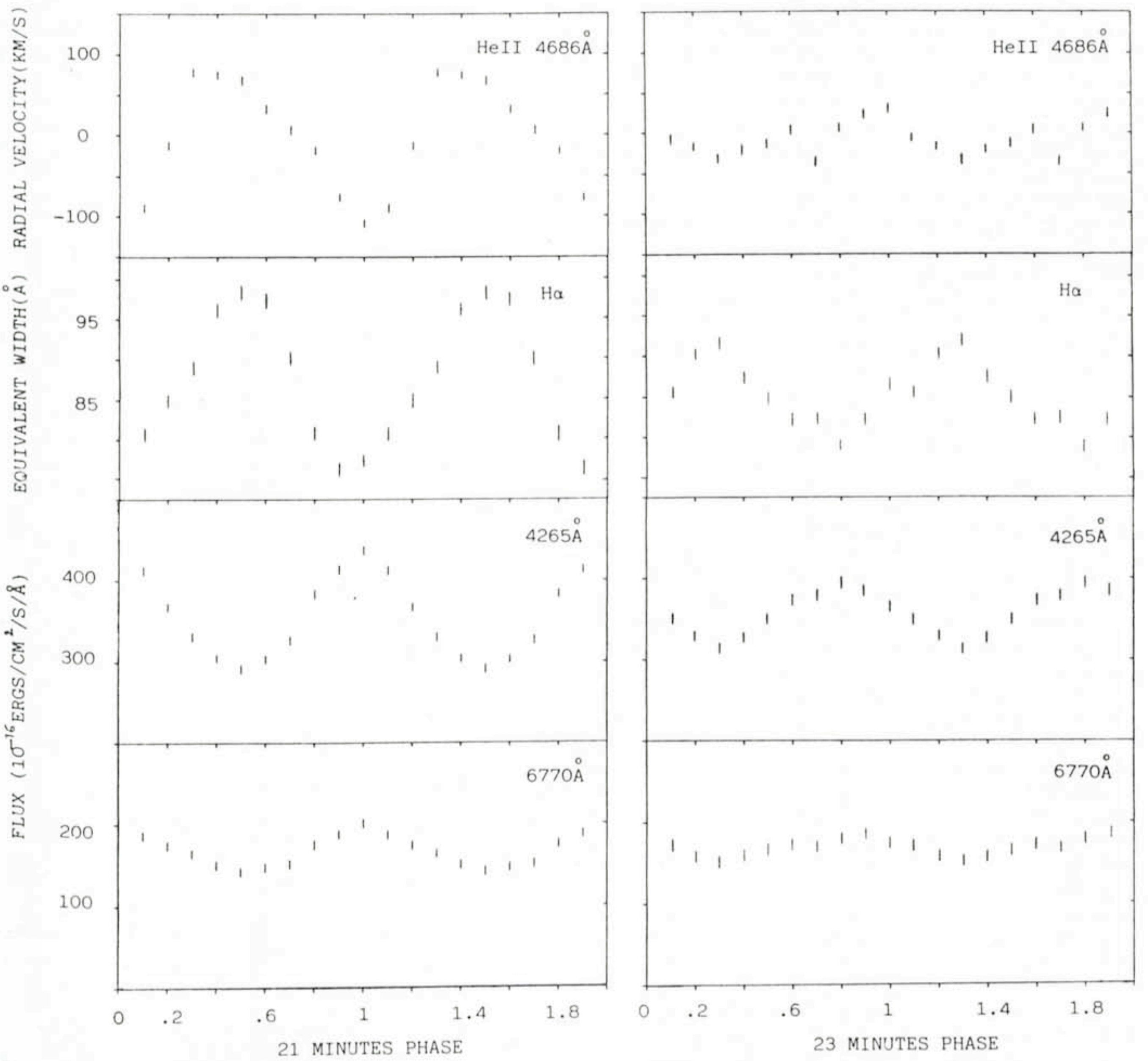


Fig. 5: *Fluxes at 6770 Å and 4265 Å, equivalent widths of Hα, radial velocities of He II folded with the 21-min period (left) and with the 23-min period (right) present in H2215–086.*

Note that the amplitude of the optical pulsations also implies an X-ray luminosity, responsible for the reprocessed flux, greater than the X-ray measurements. This leads to assume that a large fraction of the hard X-rays is rethermalized at lower energy. Detection of very soft X-rays or extreme UV radiation could solve the mystery of the missing X-ray radiation.

Though the detection of an accretion disk is not quite well established, we have seen that it seems reasonable to affirm its existence. On the other hand, the proposed interpretation for the pulsations requires a white dwarf sufficiently magnetized to favour an anisotropic accretion along the magnetic field. But other possible signatures of a magnetic field (i.e. linear and circular polarization, Zeeman components, cyclotron lines) have been seeked unsuccessfully in these systems. Such properties have been detected in other cataclysmic systems called "polars" in which the magnetic field of the white dwarf was evaluated to be equal to $3\,10^7$ Gauss. In these sources, the extended magnetosphere prevents the formation of an accretion disk. Moreover, a magnetic coupling between both companions occurs, leading to a synchronization of the rotation of the white dwarf with the orbital period. In the intermediate polars, the magnetic field would be too weak to achieve this synchronization and to observe its direct effects. Besides, we expect to observe a polarized radiation in infrared. Unfortunately, no such measurements have been done up to now. I think that now the reader begins to understand the origin of the name "intermediate polars". He also has to know the existence of a small group of cataclysmic variables which exhibit pulsations at very short periods, and consist of two novae DQ Her and V533 Her and a dwarf nova AE Aqr (respectively with periods 71s, 63s and 33s). Only one, AE Aqr, was detected in X-rays and shows X-ray 33s pulsations. The magnetic oblique rotator model was also suggested for these systems. But recently the disappearance of the 63s pulsations in V533 Her cast serious doubt on such an interpretation. These fast rotating objects are thought to have a weakly magnetized white dwarf ($B < 5\,10^5$ Gauss), although no direct evidence for such a field is found. With respect to their rotational period as well as the strength of their magnetic field, the "intermediate polars" are therefore located between the DQ Her type objects and the AM Her type systems (polars).

A Puzzling Source: H2215–086

While a satisfactory model has been proposed for 4U1849–31 and H2252–035, the X-ray source H2215–086 classified as an intermediate polar on the basis of strong optical pulsations with a 21-minute period does not seem to enter quite well in a similar frame. It differs slightly from the two previous sources by showing very strong He II lines, a rather flat UV continuum and pulsations with a huge amplitude (40% in V). Previous observations suggest the presence of a 23-minute period (Patterson, J., and Steiner, J. E., 1983, *Astrophysical Journal,* **264,** L61). In order to precise the nature of this system, we have carried out spectroscopic observations at the 3.6 m telescope using the IDS detector. Unfortunately, the wind was blowing too strongly at the 1 m telescope to get simultaneous photometric data. Then, after four hours of observing time we were requested by a careful astronomer on duty to shut the dome of the 3.6 m. Despite the bad wheather, these observations provided a lot of information. Thanks to very short-exposure spectra (30 seconds) with a 12 Å resolution, it was possible to detect the 21-minute pulsations in the continuum and the strongest emission lines. Search for periodicity in these individual spectra reveals clearly the 21-minute period and an additional period at 23 minutes corresponding to the beat period with the orbital one (4 hours). A possibly false pulsation at 19 min could also be present, maybe due to the total duration of the observations.

To increase the signal to noise ratio we have folded the spectra with the 21-min and 23-min periods and then determined the variations of the continuum at several wavelengths and of the Balmer and He II λ 4686 lines (intensities, equivalent widths and radial velocities) (Fig. 5). Surprisingly, the results, though well established, are rather difficult to interpret when gathered together. Let us discuss some of them. Both pulsations exhibit an energy distribution F_λ in λ^{-2} on the wavelength range 4200–6800 Å and at the maximum of the orbital period, the 23-min pulsation is at minimum when the 21-min pulsation is at maximum. In the context of the geometrical model described above and assuming that at the orbital maximum the red dwarf companion is behind the white dwarf, this would imply a pulsation arising from the accretion column while the other one is due to a heating effect. But how to explain the energy spectrum? Now, taking into account the strong variations of the radial velocities of the lines with the 21-min period (receding motion when the flux is minimum), this suggests a region of line formation in the column (the free-fall velocity being the dominant motion) and a heating origin for the 21-min pulsation, a conclusion incompatible with the previous ones based on the phasing of the 23-min and 21-min pulsations! It is obvious that no clear description similar to the one proposed above is satisfactory. The study of the spectroscopic variability of 4U1849–31 and H2252–035 has not yet been completed. It is urgent to do so in order to confirm the previous interpretation and to clear up to the confused and puzzling results of H2215–086.

Conclusion

Though the class of the intermediate polars is very little crowded, the similar properties of the four objects incite to consider them as a special group. Nevertheless, it might be possible that further observations emphasize different behaviours or on the contrary strengthen a unique model for these systems. The discovery of new pulsating sources, either from X-ray or optical observations would allow to clarify the nature of these peculiar objects. Let us hope that bad weather conditions will not prevent us from achieving these crucial observations.

Acknowledgements

I would like to express my thanks to the ESO staff members for their helpful assistance during several observing runs on La Silla.

List of Preprints Published at ESO Scientific Group

September-November 1983

276. G. Chincarini: HI Content in Cluster and Supercluster Galaxies. COSPAR/IAU Symposium in Rojen, Bulgaria. September 1983.
277. M. Rosa and J. Solf: On the Internal Kinematics of the Giant Extragalactic HII Complex NGC 604. *Astronomy and Astrophysics.* September 1983.
278. G. Contopoulos: Theoretical Periodic Orbits in 3-Dimensional Hamiltonians. *Physica D.* September 1983.
279. A. C. Danks, W. Wamsteker, P. A. Shaver and D. S. Retallack: A Near-Infrared Study of the Region l = 305°. *Astronomy and Astrophysics.* September 1983.

280. D. Baade: Discovery and Preliminary Identification of Two Retrograde Nonradial Pulsation Modes in the Be Star μCentauri. *Astronomy and Astrophysics.* September 1983.
281. C. Cao and R. N. Wilson: An Improved Prime Focus Corrector for f/3 True or Quasi Ritchey-Chrétien Primaries. *Astronomy and Astrophysics.* October 1983.
282. V. Caloi, V. Castellani, R. Nesci and L. Rossi: The Contribution by HB Stars to UV Radiation from Population II Systems. *Memorie della Società Astronomica Italiana.* October 1983.
283. A. C. Danks, S. R. Federman and D. L. Lambert: The CH Radical in Diffuse Interstellar Clouds. *Astronomy and Astrophysics.* October 1983.
284. M. Salvati: A New Geometry for Superluminal Motions. IAU Symposium No. 110: "VLBI and Compact Radio Sources", Bologna. October 1983.
285. M.-H. Ulrich: The Infrared, Optical and Ultraviolet Properties of Active Nuclei. IAU Symposium No. 110: "VLBI and Compact Radio Sources". October 1983.
286. I. J. Danziger, R. A. E. Fosbury, W. M. Goss, J. Bland and A. Boksenberg: Very Extended Ionized Gas in Radio Galaxies – II. An Optical and Radio Study of PKS 0349-27. *Monthly Notices of the Royal Astronomical Society.* October 1983.
287. C.-I. Björnsson: Pulsar Polarization as a Direct Consequence of the Emission Process. *Monthly Notices of the Royal Astronomical Society.* November 1983.
288. E. M. Sadler: Radio and Optical Observations of a Complete Sample of E and SO Galaxies. I. Radial Velocities. *Astronomical Journal.* November 1983.
289. E. M. Sadler: Radio and Optical Observations of a Complete Sample of E and SO Galaxies. II. UBV Aperture Photometry. *Astronomical Journal.* November 1983.
290. E. M. Sadler: Radio and Optical Observations of a Complete Sample of E and SO Galaxies. III. A Radio Continuum Survey at 2.7 GHz and 5.0 GHz. *Astronomical Journal.* November 1983.
291. A. F. M. Moorwood and I. S. Glass: Infrared Activity in Circinus and NGC 4945 – Two Galaxies Containing Luminous H_2O Masers. *Astronomy and Astrophysics.* November 1983.
292. L. W. Fredrick and R. M. West: A Study of Suspected Planetary Nebulae. *Astronomy and Astrophysics Supplement Series.* November 1983.
293. G. Contopoulos: The Dynamics of Galaxies. *Mitteilungen der Astronomischen Gesellschaft.* November 1983.
294. R. Svensson: Steady Mildly Relativistic Thermal Plasmas: Processes and Properties. *Monthly Notices of the Royal Astronomical Society.* November 1983.
295. G. Chincarini: Superclustering and Substructures. IAU Colloquium No. 78, Asiago, Italy. November 1983.
296. S. Cristiani and M. Tarenghi: A New X-Ray Emitting Seyfert 1 Galaxy. *Astronomy and Astrophysics.* November 1983.
297. G. Chincarini, M. Tarenghi, H. Sol, P. Crane, I. Manousoyannaki and J. Materne: The Horologium Region. I. The Data. *Astronomy and Astrophysics.* November 1983.
298. G. Contopoulos and A. Pinotsis: Infinite Bifurcations in the Restricted Three-Body Problem. *Astronomy and Astrophysics.* November 1983.

10th Meeting of the European Working Group on Chemically Peculiar Stars

H. Hensberge, Astrofysisch Instituut, Vrije Universiteit Brussel
H. M. Maitzen and W. W. Weiss, Institut für Astronomie, Universität Wien

On October 5 and 6, 1983 the European Working Group on Chemically Peculiar Stars (CP Stars, formerly called Ap Stars) convened its 10th meeting at the ESO headquarters in Garching. After the opening, Dr. Herman Hensberge from the Vrije Universiteit Brussel gave a seminar to the ESO audience on "Progress of Ap research at ESO". In what follows we shall provide the reader with the essence of his talk.

The foundation of the European Working Group on CP Stars dates back to autumn 1978 (more precisely and more astronomically: to J. D. 2443793.917) when on the occasion of a workshop on Ap stars in the Infrared, held at the Vienna Observatory, half a dozen Belgian and Austrian astronomers got together and decided that the unsatisfactory situation concerning data collecting in Ap research should be removed by coordinated planning of the observations, especially at ESO, and by more intense exchange of information concerning available, but unpublished data.

The first requirement has been met since by organizing semiannual meetings before the deadlines of ESO applications. These meetings are usually hosted by one of the collaborators of the Working Group (WG), i.e. his institute, but also by ESO. This way Vienna, Paris, Brussels, Liège, Catania, ESO-Garching, Trieste, Göttingen, Mons and now again ESO have been our meeting places since spring 1979.

The second point has been tackled by issuing so far 10 times *A Peculiar Newsletter* (eds. H. Hensberge, Gh. Deridder, W. van Rensbergen, Brussels) containing information on existing data, planned observations and submitted papers. Due to its important role it has become a worldwide means of communication and serves also the IAU Working Group on Ap Stars.

At the moment astronomers from six European countries participate actively in the WG: Austria (Maitzen, Rakosch, Weiss), Belgium (Deridder, Hensberge, Manfroid, Mathys, Renson, van Santvoort), France (Floquet, Gerbaldi, Megessier, Morguleff), Germany (Hössler, Kroll, Schneider, Vogt, Voigt), Italy (Catalano, Faraggiana), Yugoslavia (Pavlovski). There is some cooperation also with Switzerland and with eastern and non-European countries.

Our scientific goal is to collect data on the peculiar properties of the CP stars which encompass slower rotation compared to the normal stars, strong metal line spectra, strong organized magnetic fields, often with reversing polarity, strong spectrum variability and recently pulsational instability.

The model of the "Oblique Rotator" which foresees a non-zero angle between the magnetic and rotation axes in these stars explains successfully the observed phase relationship between these phenomena.

Unexplained, however, is the question of the origin and the evolutionary time scales of these phenomena, i.e. magnetic fields, abundance anomalies, slow rotation. A number of theories and hypotheses have been put forward to explain the formation of peculiarities. Havnes and Conti (1971) have qualitatively shown that the interaction of the rotating magnetosphere of a magnetic Ap star with the interstellar medium produces both the deceleration of stellar rotation and the building up of abundance anomalies around the magnetic poles. Michaud (1970) takes diffusion of elements due to the selective effect of the radiation field on different elements as the mechanism for abundance anomalies. Strittmatter and Norris (1971) advocate mass loss along the polar field lines as cause for breaking of the rotation, while Fleck (1981) recently proposes hydromagnetic deceleration by the stellar magnetic field without mass loss.

The important question, where the strong magnetic fields come from, is answered either by the fossil field hypothesis or by a dynamo theory.

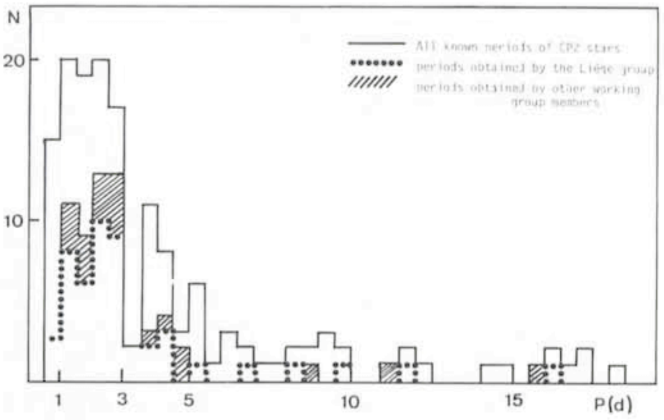


Fig. 1: *Histograms of published rotational periods (in days) of CP2 stars.*

What can observers contribute to clear up the darkness about the origin and the mechanisms giving rise to the appearance of peculiar and magnetic stars constituting roughly 10% of the main-sequence stars of spectral types B5–F0?

Certainly, we can give theory strong constraints by finding out whether or which significant evolution of the observed peculiarities takes place on the main sequence. Thus, one direction of our efforts is the investigation of the rotational periods of the CP stars and their distribution with spectral type. Fig. 1 shows a histogram of rotational periods and visualizes the important contribution made by the colleagues of Liège and other members of our WG.

While historically some of the variation periods (= rotation periods according to the Oblique Rotator model) were obtained on the base of spectrum variability analyses, our work is nearly exclusively based on the search for photometric variability which very conveniently has been done at one of the small telescopes on La Silla (the 50 cm Danish, the 50 cm ESO and the 60 cm Bochum telescope).

As pointed out above, a general feature of the whole group of CP2 stars is slow rotation. This statement, however, does not apply to each object in this group. The reality is better described by saying that one finds CP2 stars with periods comparable to those of normal stars (= one day and less) of the same spectral domain, and also slower rotation of all degrees up to such long rotation periods that some stars take even many years to spin around their axes. Thus from this observational fact we may safely conclude that slow rotation is not necessary as starting condition for peculiarity, but is rather the result of the real cause of it.

It appears that too many CP2 stars are very slow rotators. As one result of our work we found that at least 4% of them have periods longer than one month, but it could be even as large as 16%. Therefore we started a campaign in our WG for monitoring apparently constant CP2 stars over time intervals of years. It will be very important to obtain the distribution of long-period stars over the whole spectral range of peculiar stars, since the time scale of braking can be checked considering the different main-sequence life times. A complete survey of the rotational behaviour of CP2 stars should clarify whether a single or more than one mechanisms/parameters are responsible for the rotational braking. A bimodal distribution in the histogram of rotational periods would point to the latter situation.

Some age information will also be available after the location of CP2 stars perpendicular to the galactic plane will have been established. After Vogt and Faundez (1979) had published their Strömgren photometry for 340 southern CP2 stars (obtained at the ESO 50 cm telescope) we started in our WG a programme for measuring β indices of these stars at the 50 cm Danish telescope. After a discussion of the applicability of Crawford's (1978) luminosity calibration to peculiar stars we should be able to map the galactic distribution of these stars.

A more direct input of the influence of time on peculiarity parameters will be received by observations of peculiar stars in open clusters. A number of studies of that kind have been carried out by different authors, mainly attempting to derive the frequency of peculiar stars in clusters as a function of age. The search for CP2 stars has always been based on spectroscopic identification. Since the average brightness of CP2 stars in open clusters is several magnitudes lower than that of the peculiar field stars, the spectroscopic search method implied enormous amounts of observing time at relatively large telescopes. As a result, the number of clusters surveyed is too low for significant statistical results to be derived, and a strong bias for the more luminous (= Silicon) peculiar stars was introduced.

Our WG has been carrying out a programme (starting Oct. 1979) searching for CP2 stars in open clusters using the photoelectric method proposed by Maitzen. This technique measures the depth of the broad band flux depression feature around 5200 Å by 3 intermediate-band filters centred on 5000, 5215 and 5480 Å, respectively (they are called "$g1$, $g2$ and y"). An index "a" is formed by subtracting the measurement in $g2$ from the mean of $g1$ and y. This index will deviate by 0.01 or more (up to hitherto 0.1 mag) from the index of a normal star of the same colour ($b–y$, $B–V$ or else) if the star exhibits a λ 5200 depression feature. Maitzen and Vogt (1983) have very recently shown by their observations of 339 southern CP2 stars (obtained at the ESO 50 cm telescope) that virtually all of the spectroscopically identified CP2 stars show a significant deviation $\Delta a = a(\text{CP2}) - a(\text{normal})$. Therefore, Δa is an ideal tool for detecting CP2 stars, since it is based on a broad-band feature, measurable with rather small size telescopes.

So far we have carried out the search for CP2 stars in 24 open clusters, for 9 clusters the results have been published (Maitzen and Hensberge, 1981; Maitzen and Floquet, 1981; Maitzen, 1982; Maitzen and Wood, 1983) and for 4 others preliminary results are available.

We hope to double the number of clusters surveyed in the next 3 years. The overwhelming majority of observations was obtained at the ESO 50 cm and 1 m telescopes. Some observations were made at CTIO (1 m), Catania (90 cm) and Hvar (Yugoslavia, 60 cm). In Fig. 2 we present a plot of the cluster results versus the logarithm of age for the first 13 clusters studied. From this we cannot yet deduce a clear-cut dependence of the frequency of CP2 stars on age, but obviously much more data should be obtained before reaching any reliable conclusion.

In addition to using Δa as identification criterion for CP2 stars one can consider this index as parameter quantitatively describing the peculiarity of the stars and try to find whether it exhibits any systematic variation with time (= age of the cluster). Of course, one tries to relate the phenomenological

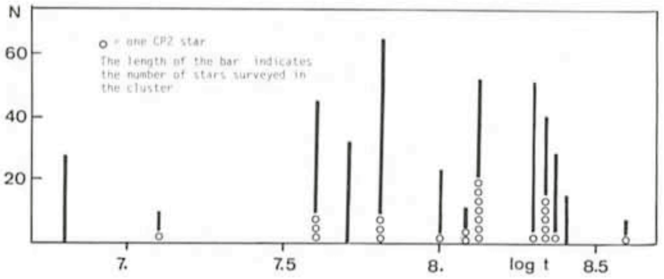


Fig. 2: *Result of CP2 star search in 13 open clusters as a function of the logarithm of age.*

peculiarity parameter to a physical mechanism. Broad autoionization features of Si II have been proposed to account for most of the λ 5200 depression. Other authors have suggested bound-free transitions, or just a local increase of the number of absorption lines around λ 5200. All of these explanations fail to describe consistently the behaviour of the λ 5200 feature. A more promising approach is to consider the empirical correlation of the strength of the λ 5200 feature found by Cramer and Maeder (1980) with the strength of the magnetic field. This relationship saturates at 5,000 Gauss. We can therefore ask, whether Δa is a measure of the (scalar) surface magnetic field. Increase of opacity can be explained by increase of Zeeman splitting of the individual lines with increasing field strength. This increase halts when the sigma and pi components of the magnetic splitting are fully separated; thus we observe the saturation of this effect. For lines on the flat part of the curve of growth the Zeeman splitting should produce a net linear polarization since the pi component can no longer be as strong as both sigma components together. In regions with enhanced line frequency, such as the λ 5200 feature, one can therefore hope to observe a measurable linear polarization if there is a significant transversal magnetic field component. A programme to measure this linear polarization in CP2 stars is under way in the framework of our WG. From a preliminary analysis of the variation of Δa during the rotational cycle for about 30 CP2 stars (based on observations at the 60 cm Bochum telescope, but also at the 50 cm ESO and the 90 cm Catania telescopes) we draw the conclusion that the behaviour of Δa is in accordance with the variation behaviour of the surface magnetic field.

Hence, we obtained the very valuable result that the broadband index Δa represents (with the restriction of the 5kG saturation) the magnetic field strength in CP2 stars. Thus, we can expect to assess any possible dependence of the magnetic fields on age measuring Δa for CP2 stars in clusters. This increases the value of Δa over a mere detection criterion for CP2 stars.

Another parameter – besides the magnetic field – justifies to call CP2 stars truly peculiar: the observed overabundances of Silicon, Strontium, Rare Earths and the Iron Group elements. Overabundances by a factor of up to 10^5 relative to the sun are reported. However, such extreme overabundances are more and more contested since modern atomic data, mainly the oscillation strengths of the exotic elements, do not seem to support such large factors. Furthermore, improved models of CP2 star atmospheres which take into account line blanketing of more than 900,000 lines also support this trend. But in any case, nobody doubts that some elements are clearly overabundant in CP2 stars. The most widely accepted theory for explaining the chemical surface anomalies is the diffusion theory put forward by Michaud (1970) and subsequently further developed by other authors. Diffusion acts individually on the chemical elements in the stellar atmospheres, depending on the balance between gravitational settling and radiation pressure lifting (the latter depending on the opacity provided by the individual elements under the actual atmospheric conditions). Therefore, diffusion will modify the surface abundances in both directions: some elements will become overabundant, while others will show up as underabundant. The latter applies to Oxygen, Helium, Carbon, Nitrogen and Neon, among others.

Presently, our WG members Faraggiana, Floquet, Gerbaldi and van Santvoort try to determine these underabundances with an unprecedented accuracy using the RETICON detector with the CAT Echelle Spectrometer. A major problem is the underabundance of Magnesium predicted by the diffusion theory. The results obtained so far, however, show that Mg has essentially solar abundance. Observations of the resonance lines at 2795 and 2803 Å for very few stars are in favour of a slight underabundance of Mg II. Observations of the near IR lines of Mg II will permit to extend the analysis to as wide a range as possible in wavelength in order to obtain information from atmospheric layers at different depths.

The cosmic abundance of Li, Be and B are very low compared to those of the neighbouring elements. Therefore one can expect that only their resonance lines will be observable. The lithium abundance, e.g., can be determined only by the resonance doublet of Li I at 6707 and 6708 Å. These observations were recently performed at La Silla and the data are currently evaluated.

Another fascinating aspect of CP2 stars is the instability against pulsation – at least of some of them. As reported recently by Kurtz (1982) and, in this journal by Weiss and Schneider: (1983a), radial as well as non-radial pulsation has been detected among these stars. Currently we are observing the known non-radially pulsating CP2 stars with the 90 cm Dutch telescope and the Walraven five-channel photometer in order to identify the pulsation modes. A reliable mode identification is crucial for a theoretical discussion of the pulsation frequency spectrum. Pulsation of CP2 stars is potentially a powerful tool for learning more about the structure of these stars and in particular the role of their relatively strong magnetic fields. The Walraven VBLUW photometer at ESO is an excellent instrument for determining the colour dependence of pulsation. With these photometric data on the pulsational behaviour we will be able to put constraints on possible modes based on a linear non-radial pulsation theory.

The surface brightness (*S*) is defined as the flux radiated from the visible stellar hemisphere towards the observer and is expressed in magnitudes. The flux (*F*) is given by the ratio of the total luminosity (*L*) to the surface area (*A*). Wesselink (1969) has shown that the surface brightness in the *V* band is nicely correlated with a colour index such as (*B–V*) and is therefore directly observable. In a first order approximation one can calculate the brightness variation according to:

$$\Delta m = \Delta S - 1.086 \times \Delta A/A$$

The variation of the projected area of the photosphere ($= \Delta A/A$) can be determined from radial velocity measurements after appropriate corrections for limb darkening and projection effects have been applied. The fundamental papers in this field are published by Dziembowski (1977), Balona and Stobie (1979a, b) and Balona (1981).

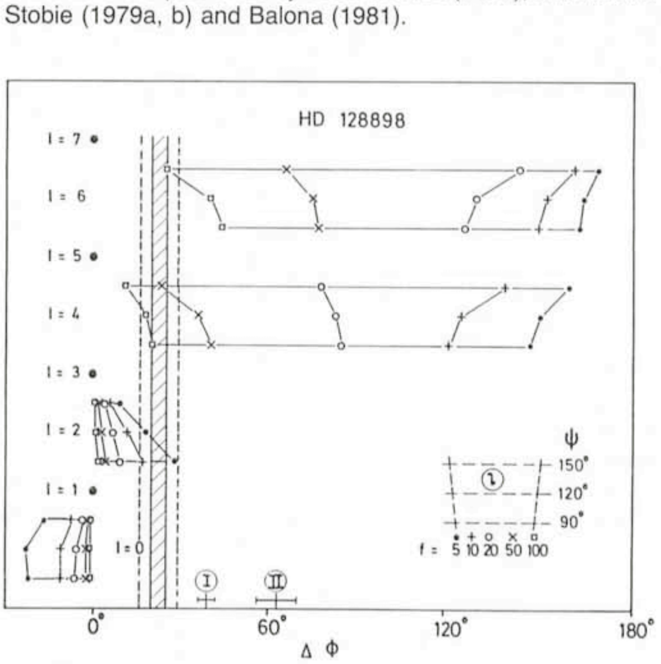


Fig. 3: *Pulsation mode determination diagram. For details see text.*

Basically, one uses diagrams like that given in Fig. 3 for mode identifications (Weiss and Schneider, 1983b). The abscissa is calibrated in phase differences between brightness and flux variations. The linear pulsation theory tells that this phase difference depends not only on the pulsation mode *l*, but also on the phase lag (ψ) between brightness and radial velocity variations and on the value of *f*, a parameter which characterizes the relative importance of the flux variations in the total luminosity variation. A ψ of about 120° can be expected for CP2 stars. The shadowed area in Fig. 3 represents our observed phase difference for HD 128898 (α Cir), ① represents the corresponding value for HD 101065 and ⓘ for HD 83368 as determined by Kurtz (1982). From our figure it is evident that more observations and in particular an improved theory are required, if one considers that *f* larger than 50 has not yet been determined in pulsating stars of comparable temperature and that Kurtz identified the pulsation modes of HD 101065 and HD 83368 as *l*=1 and 2 modes on the grounds of his oblique pulsator model. For us it seems that the only way out of the dilemma is to try to get high accuracy spectral line variations for the brightest pulsating CP2 stars and to use this information for an independent mode identification. A corresponding telescope time application is submitted to ESO.

This is the substance of the report of Dr. Hensberge, which was followed by a discussion from the ESO audience. The WG on CP2 stars then continued its work in one of the conference rooms of the ESO headquarters. This way the most recent results were discussed as well as the imminent observing runs and finally the individual applications for observing time for the next period. The next (spring) meeting of the WG will be held in Zürich or Paris.

The Working Group is very grateful to ESO for the hospitality shown once more. We hope that this time we could give the opportunity for some participation by preparing and presenting a report to the ESO public.

References

Balona, L. A.: 1981, *Mon. Not. Roy. Astr. Soc.* **196,** 159.
Balona, L. A., Stobie, R. S.: 1979a, *Mon. Not. Roy. Astr. Soc.* **187,** 217.
Balona, L. A., Stobie, R. S.: 1979b, *Mon. Not. Roy. Astr. Soc.* **189,** 649.
Cramer, N., Maeder, A.: 1980, *Astron. Astrophys.* **BB,** 135.
Crawford, D. L.: 1978, *Astron. J.* **83,** 48.
Dziembowski, W.: 1977, *Acta Astr.* **27,** 203.
Fleck, R. C., Jr.: 1981, in: 23ème Coll. Intern. d'Astrophysique, Liège, p. 341.
Havnes, O., Conti, P. S.: 1971, *Astron. Astrophys.* **14,** 1.
Kurtz, D. W.: 1982, *Mon. Not. Roy. Astr. Soc.* **200,** 807.
Maitzen, H. M.: 1982, *Astron. Astrophys.* **115,** 275.
Maitzen, H. M., Floquet, M.: 1981, *Astron. Astrophys.* **100,** 3.
Maitzen, H. M., Hensberge, H.: 1981, *Astron. Astrophys.* **96,** 151.
Maitzen, H. M., Vogt, N.: 1983, *Astron. Astrophys.* **123,** 48.
Maitzen, H. M., Wood, H. J.: 1983, *Astron. Astrophys.* **126,** 80.
Michaud, G.: 1970, *Astrophys. J.* **160,** 641.
Strittmatter, P. A., Norris, J.: 1971, *Astron. Astrophys.* **15,** 239.
Vogt, N., Faundez, M.: 1979, *Astron. Astrophys. Suppl.* **36,** 477.
Weiss, W. W., Schneider, H.: 1983a, *The Messenger* No. **33,** 7.
Weiss, W. W., Schneider, H.: 1983b, *Astron. Astrophys.*, submitted.
Wesselink, A. J.: 1969, *Mon. Not. Roy. Astr. Soc.* **144,** 297.

Automatic Parameter Extraction for the 16,000 Galaxies in the ESO/Uppsala Catalogue

A. Lauberts and E. A. Valentijn, ESO

Introduction

Since the completion of the ESO/Uppsala survey for southern galaxies last year a follow-up study of that survey has been prepared. The main purpose of the original survey was *to find and classify* galaxies on the ESO Quick Blue Survey (QBS). The copy plates were visually inspected and all parameters such as position, size and morphology were determined with the help of the human eye. A close inspection of the QBS down to the plate limit of ~ 21 mag would have revealed about 1 million galaxies. For the ESO survey it was decided to restrict the number of galaxies by including only those objects with an angular diameter larger than 1′. This limit roughly corresponds to the 15th magnitude and also had the advantage that the detected systems showed enough structure to classify them morphologically. 14,000 galaxies passed the angular size criterion and together with ~ 2,000 peculiar galaxies, ~ 1,000 star clusters and ~ 1,000 planetary nebulae they were brought together in a single volume (ESO/Uppsala Catalogue, A. Lauberts, 1982).

As soon as ESO initiated the new red survey on IIIa-F emulsion, plans developed to extract all possible photometric and morphological parameters from the complete set of B and R survey plates. At that time less than 10% of the ESO catalogue galaxies had published magnitudes and almost no red photometry existed for these objects. Detailed photometry was known for perhaps 100 of the brightest objects. Here we describe an extensive project that aims to calibrate both the R and B survey plates and to extract automatically both photometric and morphological parameters for all the galaxies present in the catalogue. A flow chart linking the different steps of the project is given in Fig. 1. Essentially the project contains the following parts:

1. Scan the 16,000 galaxies with the PDS on 606 Blue and 606 Red original ESO survey plates.
2. Bring together existing photometry in a catalogue and add complementary photometry using own measurements at the ESO 1 metre telescope.
3. Calibrate the plates and determine the properties of the galaxies automatically using the ESO VAX computers.
4. Produce a catalogue on paper, magnetic tape and possibly on video disk.
5. Investigate the data base scientifically.

By October 1983 over 600 plates, mostly in B colour, have been scanned, a preliminary catalogue of photometric standards has been compiled and satisfactory versions of the software are in operation on the VAX computers.

Below we give some more detailed information on the different steps and present some preliminary results of our test field No. 358, covering the Fornax cluster.

Digitizing the Plates

As soon as a plate is manually positioned in the PDS (emulsion up) and the machine is set to zero density at the plate fog level, the scanning procedure is fully under control by the

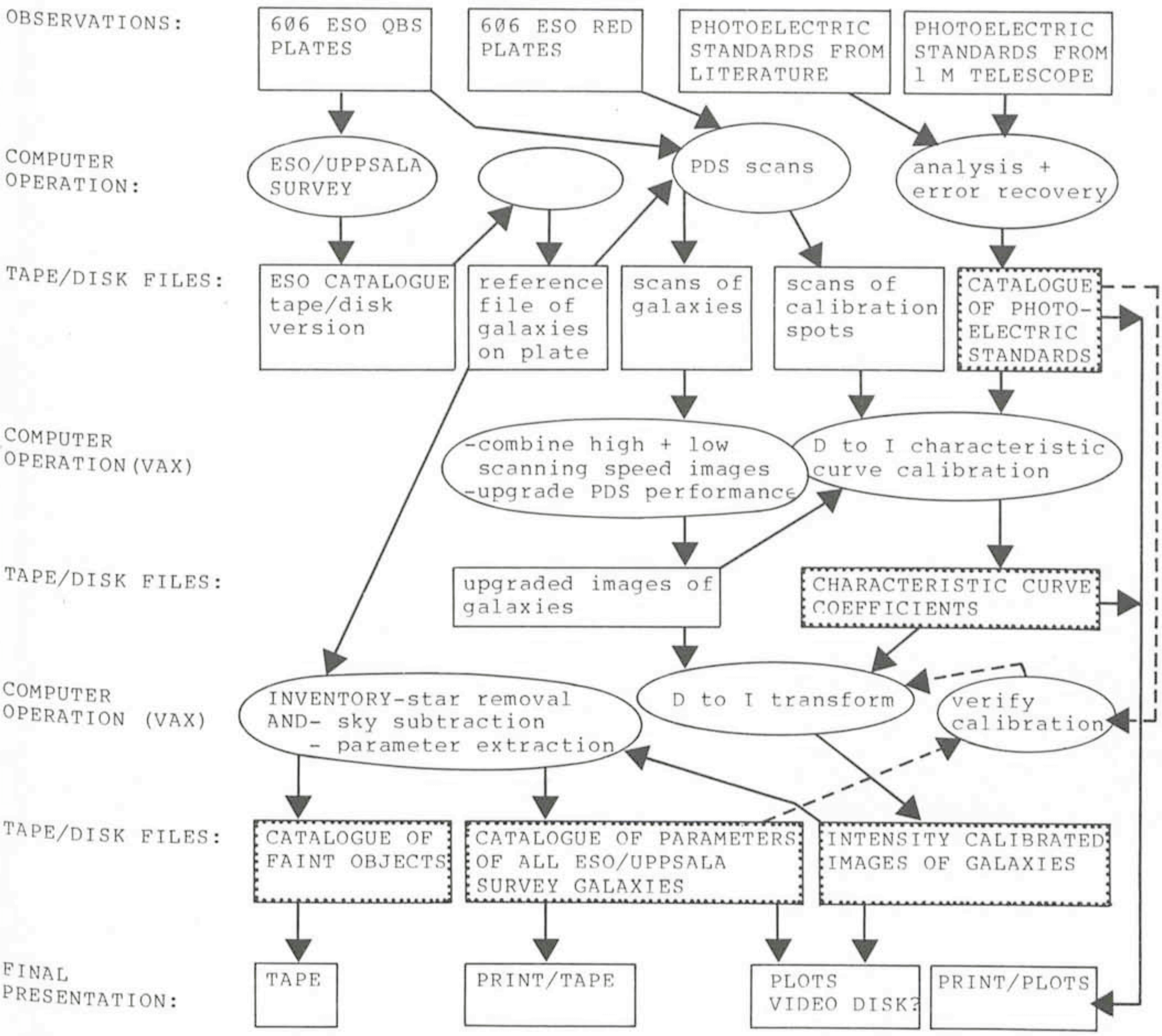


Fig. 1: *Flow chart of the automatic parameter extraction listing the computer operations and the resulting disk files. Marked disk files indicate that they provide a useful data base to the astronomical community.*

HP computer. From a reference file the computer selects and is able to find the objects to be scanned and determines the size of the scanning area. An area as large as three times the visible size (which corresponds to 25^m B surface brightness) of the object is scanned at high speed (20 mm/sec). A second scan of the central area of presumably much higher density is performed at a low speed (2 mm/sec). Later, the two images are combined into one using the VAX machine. The artifacts of the logarithmic amplifier of the PDS which produces asymmetric scan profiles at high densities are mainly recovered by a 2-dim interpolation.

The scanning procedure is relatively quick, the main bottleneck in this step being the availability of the Red Survey plates which are still being taken.

Photometric Calibration

During three runs (1982–1983) at the ESO 1 m telescope, multi-aperture photoelectric U, B, V, R, I measurements of 200 standard elliptical and SO galaxies have been acquired, selecting one object per survey field. Together with existing measurements 6,000 entries have been created in a disk file for the photometric calibration of the survey plates. Polynomial fits to plots of observed magnitude versus the log of the aperture used have been made for every standard galaxy. Next, the computer was instructed to make a plotted version of the "photometric catalogue" drawing the radial distribution of the V, U–B, B–V and V–R measurements, together with the polynomial fits. This served to recover any mishaps in the observations or the polynomial fits.

The characteristic curve is found by fitting $\log I = A^*\log(D_{sat}-D) + B^*\log(D-D_{fog}) + C$ to the standard galaxy aperture photometry and the calibration spots for the lower densities. This formula has been adopted from Llebaria and Figon in "Proceedings on Astronomical Photography", Nice 1981. The resulting transformation coefficients are stored in disk files. At present we have the data to calibrate ~ 400 Blue and ~ 250 Red original plates. Much more data are obviously still needed for the Red colour.

When more than one standard galaxy is available for a particular field, only one is used for the determination of the characteristic curve, leaving the other standards for a verification of the residuals of the photoelectric versus photographic measurements. An example of such a verification is given in

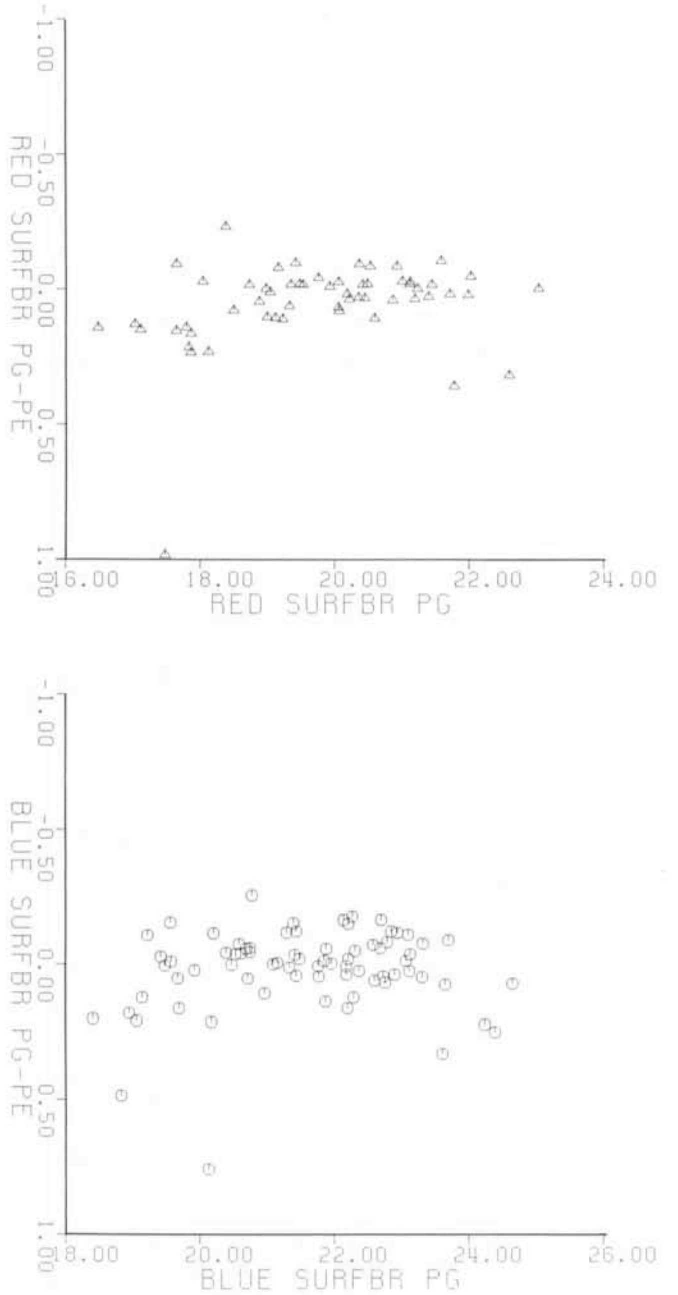


Fig. 2: *The residuals of photographic and photoelectric measurements versus the red and blue surface brightness is given in the upper and lower diagram respectively. Data points represent data of ~ 20 galaxies in the field 358. The dispersion is larger in the blue colour due to the higher noise in the IIa–O emulsion used for the QBS.*

Fig. 2 and shows a mean residual less than $0\overset{\mathrm{m}}{.}08$ for the red surface brightness and $0\overset{\mathrm{m}}{.}12$ for the blue surface brightness. The final photometric system will be determined through a study of $m_{pg} - m_{pe}$ residuals of all B and R plates simultaneously. The dotted line in the flow chart in Fig. 1 represents this "loop" in our calibration. Providing a catalogue with standard galaxies and the list of coefficients of the characteristic curve can be considered as the first two products of our project.

The Automatic Parameter Extraction

Once the characteristic curve coefficients of a plate have been determined, the images of the galaxies are converted from density into intensity and are ready for further analysis. Using a sequence of software routines the following is obtained in one main programme. First a version of the programme INVENTORY is run which detects and classifies all objects present in a single frame of a target galaxy and whose surface brightness exceeds that of the sky by a factor two. On average about 20 such objects are found per frame and their positions, magnitude and classification are calculated using a reference point spread function. The data are stored in a separate disk file for later investigation. In the future this data bank will be used to search for peculiar objects, such as quasars and novae, in the neighbourhood of the target galaxies. For instance, an automatic survey of objects with a certain colour excess will be feasible. The INVENTORY programme finally creates an image with all neighbouring objects subtracted from the input image. Next, as a first step in a string of our own routines, which we have called AND, the sky brightness distribution is approximated by a plane using 8 surrounding subregions, four of them being close to the corners. After the subtraction of the sky we are finally set to extract the photometric and structural information from the images. Radial B, R and B–R profiles are stored in the disk catalogue together with overall elongations and position angles from an octants comparison. For elliptical and SO galaxies ellipses are fitted to the isophotes determining the

IAU Colloquium No. 79

Very Large Telescopes, their Instrumentation and Programs

ESO, Garching, 9–12 April, 1984

Scientific Organizing Committee:
R. Angel, R. Cayrel, O. Citterio, M. Longair, G. Münch, N. V. Steshenko, J.-P. Swings, M.-H. Ulrich (Chairman), S. van den Bergh, H. van der Laan.

The meeting will last four days. Two and one half days will be devoted to the questions of Telescope design and fabrication, Domes, Sites, Instruments and Components:
- Primary mirrors, structures, support systems
- Active optics, wind loading, dome seeing, properties of the atmosphere
- Radiometric properties of telescopes
- Instrument matching in spectroscopy and direct imaging
- Large format detectors in the optical and IR
- Interferometry and speckle methods

One day will be allotted to Reviews of the Astronomical Programs and one half day to a panel discussion and a summary.

Invited Speakers include:
R. Angel, J. Beckers, H. Butcher, V. Castellani, F. Forbes, P. Léna, F. Low, R. Lynds, B. Mack, J. Nelson, H. Richardson, F. Roddier, R. Tull, J. Wampler, G. Weigelt, N. Woolf.

Contact Address:
IAU Colloquium No. 79, Ms. Christina Stoffer, European Southern Observatory, Karl-Schwarzschild-Straße 2, D-8046 Garching bei München, F.R.G., Telephone (89) 32006-0, Telex 52828222 eo d

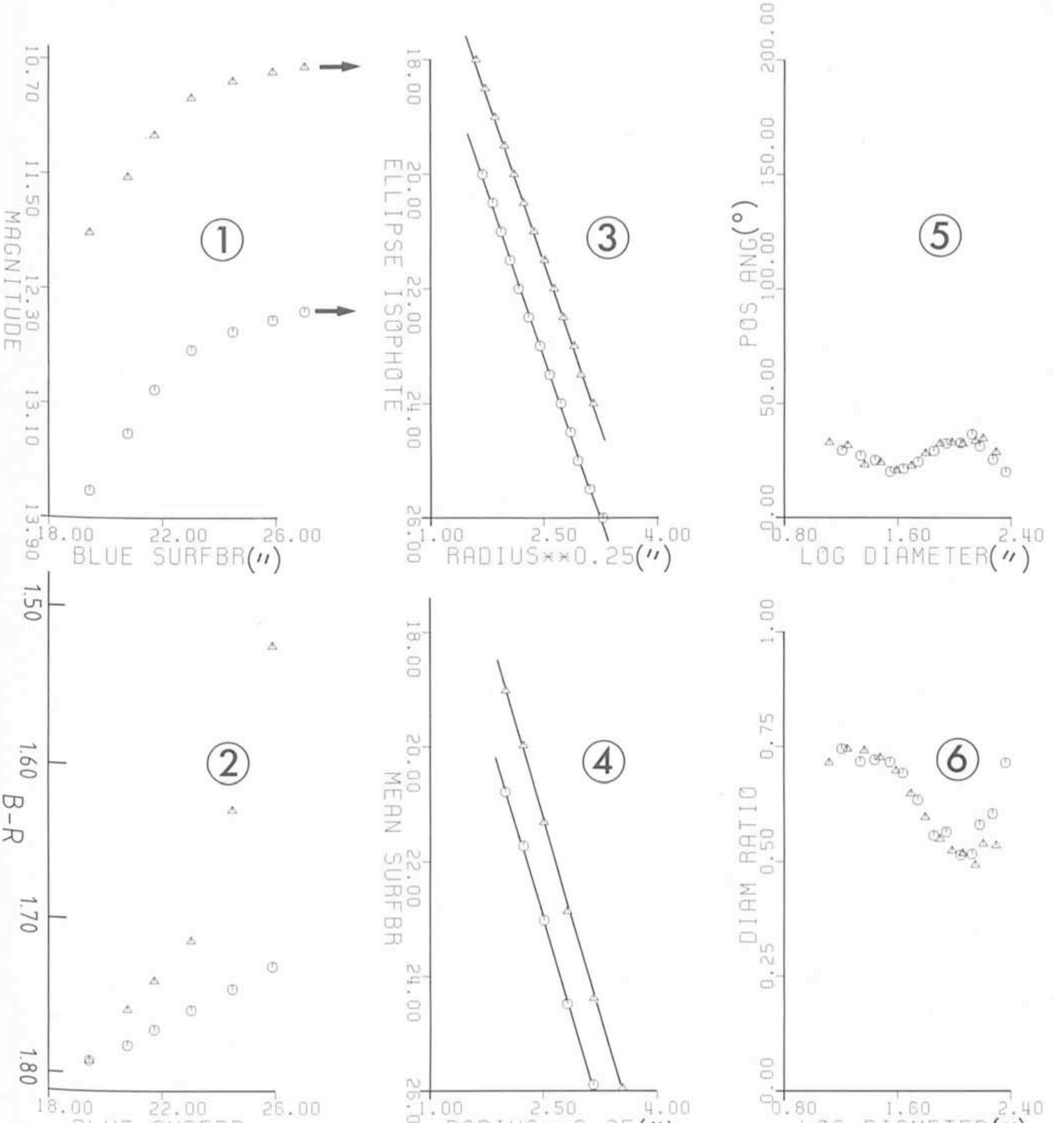


Fig. 3: *Photographic properties derived for the SO galaxy ESO 358–G38 in the Fornax cluster.*

1. MAGNITUDE vs BLUE SURFACE BRIGHTNESS. Integrated blue (circle) and red (triangle) magnitudes versus mean blue surface brightness in mags per square arcsec, sampled in ellipses according to the representative overall structure of the galaxy. For surface brightness < 22 the photographic values are replaced by, if available, more accurate photoelectric values in circular apertures.

2. B–R vs BLUE SURFACE BRIGHTNESS. Integrated (circle) and differential (triangles) B–R colour versus blue mean surface brightness.

*3. MEAN SURFACE BRIGHTNESS vs RADIUS** 0.25. Mean surface brightness versus major radius (arcsec) to the ¼ power. Data samples in ellipses of fixed shape and orientation, according to the representative overall structure of the galaxy.*

*4. ELLIPSE ISOPHOTE vs RADIUS** 0.25. Ellipse approximation to blue (circle) or red (triangle) isophote on smoothed image versus major radius (arcsec) to the ¼ power. Data sampled in the appropriate local ellipses as determined by the ellipse fitting.*

5. POSITION ANGLE vs LOG DIAMETER. Position angle (degrees) versus log major diameter (arcsec) for blue (circle) and red (triangle) ellipses fitted to isophotes.

6. DIAMETER RATIO vs LOG DIAMETER. Axial ratio versus log major diameter of ellipses fitted to isophotes. Seeing and low signal to noise ratio near the sky background both have a tendency to round off elongated objects.

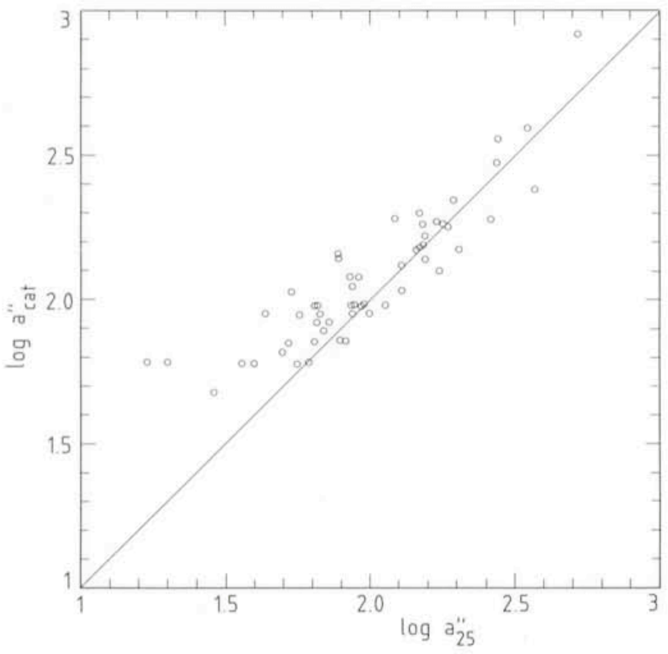


Fig. 4: *The angular size major diameter as listed in the ESO/Uppsala Catalogue versus the computer-determined maximum angular size at the Blue 25^m surface brightness.*

radial change of their eccentricity and position angle (isophotal twisting). We aim to obtain all these parameters for the 16,000 survey galaxies and to publish them on paper. However, a plotted version of the catalogue seems also very useful as is illustrated by Fig. 3 which presents one page of such a catalogue. The SO galaxy NGC 1389/ESO 358–G38 has a total m_R = 10.8 (panel 1), a central B–R = 1.80 and a bluer halo of colour B–R = 1.50 (panel 2), follows perfectly an $r^{1/4}$ law profile (panels 3 and 4) and shows, consistently on B and R plates, clear evidence for isophotal twisting (panel 5) and has a varying axial ratio (panel 6). The actual determination of the structural properties of the spiral galaxies requires an additional investigation using Fourier transform techniques, which is now under consideration.

The data for the 70 galaxies in our test field also give some results which are of general use. Fig. 4 shows that for objects with a diameter larger than 1′ the angular size as listed in the ESO/Uppsala catalogue actually corresponds closely to the angular size at 25^m Blue surface brightness. Fig. 5 shows an angular size-magnitude diagram for the same 25^m B diameter. With some caution (separation into morphological types!) this diagram can thus be applied to roughly estimate (~ 0.5^m accuracy) the B^{25} total magnitude from the angular sizes (major and minor diameters combined) as listed in the catalogue for all objects.

Once the catalogue has been completed, many items can of course be studied. We are highly interested in studying the influence of the environmental conditions of galaxies on their fundamental properties. Since the sample contains galaxies in all sorts of environments ranging from purely isolated systems to members of rich clusters or superclusters this objective becomes feasible. Systematic correlative studies between galaxy core radii, colours, colour gradients and isophotal twisting will be possible. An example of such a study is illustrated in Fig. 6 where we have plotted the central B–R colour of the Fornax galaxies versus the colour gradient between those centres and the outer haloes of the galaxies. There seems to be a general trend for galaxies with a relatively

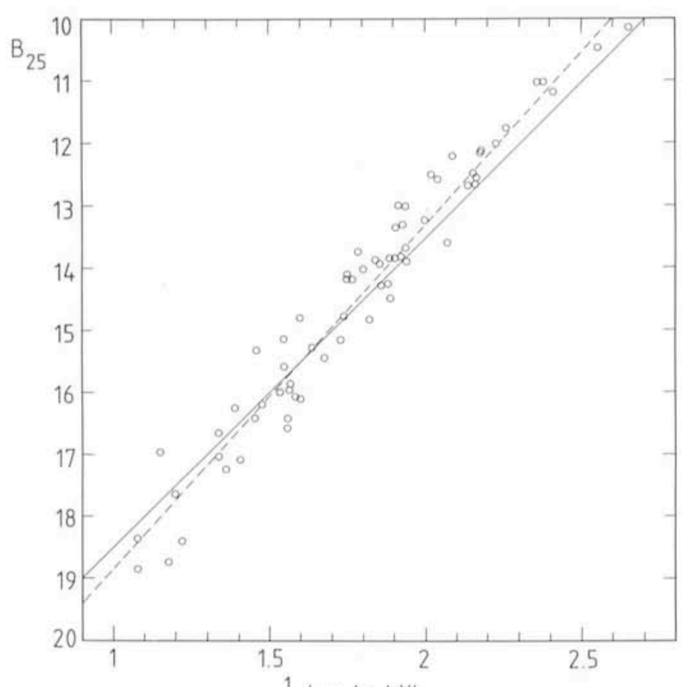


Fig. 5: *The characteristic angular size – magnitude relation determined on the QBS plate of the Fornax cluster. The characteristic angular size was calculated from the square root of the product of the major and minor axis. The dashed line represents a fit to the data. Distance variation moves all objects along the indicated solid line of slope –5. All values are automatically determined by the computer programme.*

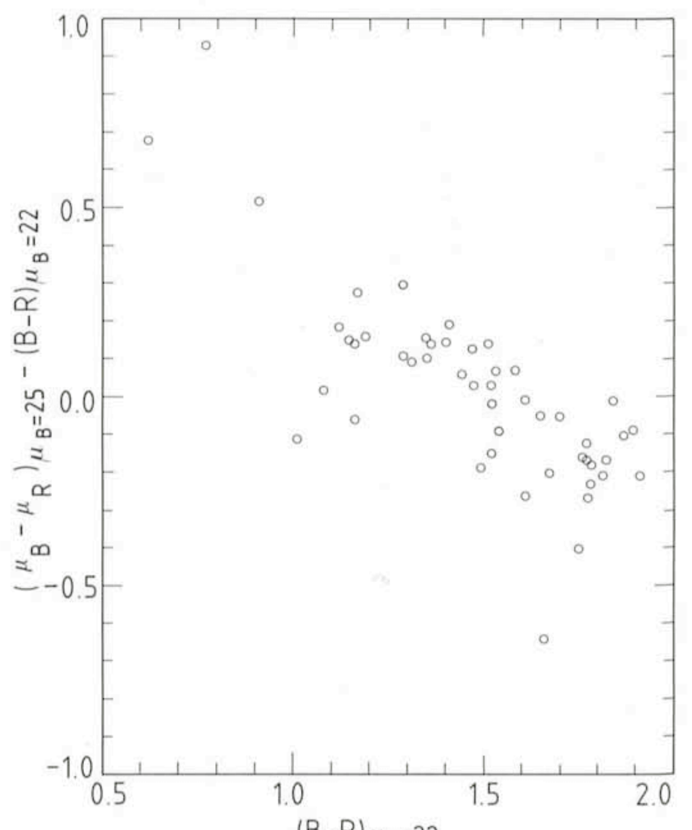


Fig. 6: *The total central B–R colour inside the 22^m blue surface brightness level versus the colour difference between this central colour and the local B–R colour at a 25^m blue surface brightness.*

blue central colour to have a redder halo, while those systems with a relatively red central colour (ellipticals and SOs) seem to have a bluer halo colour.

At the bottom of the flow chart in Fig. 1 we have indicated the possible presentation of the acquired data bases. Eventually our final data base of 16,000 galaxies will be expanded by two to three orders of magnitude compared to the preliminary results for the Fornax cluster. By then we will have acquired an unprecedented set of properties of Southern Hemisphere galaxies. The size of the sample and the uniform approach as attempted in this project should allow us to study the universe in an unbiased way.

The 2.2 m Telescope is Ready

M. Tarenghi, ESO

The 2.2 m Zeiss telescope is the last telescope to have arrived on La Silla, thanks to a 25-year loan to ESO from the Max-Planck-Gesellschaft (MPG) who will receive for their contribution 25 % of the observing time. ESO assumed responsibility for the installation of the telescope, the arrangement of necessary modifications, and construction of the building and dome according to specifications agreed with the MPG. ESO will also assume responsibility for the maintenance and operation of the telescope.

The erection of the telescope began on February 15, 1983, and as a result of a collaboration of qualified personnel from Zeiss and MAN and the services of many ESO technicians, we succeeded in obtaining the "first light" on the night of June 22, 1983. During the following weeks the telescope was used for optical, mechanical and electronic tuning. The end of the bad winter weather made it possible to start using the telescope with the photographic camera, the B & C spectrograph plus CCD camera, or a Danish RPCS detector and the CCD camera

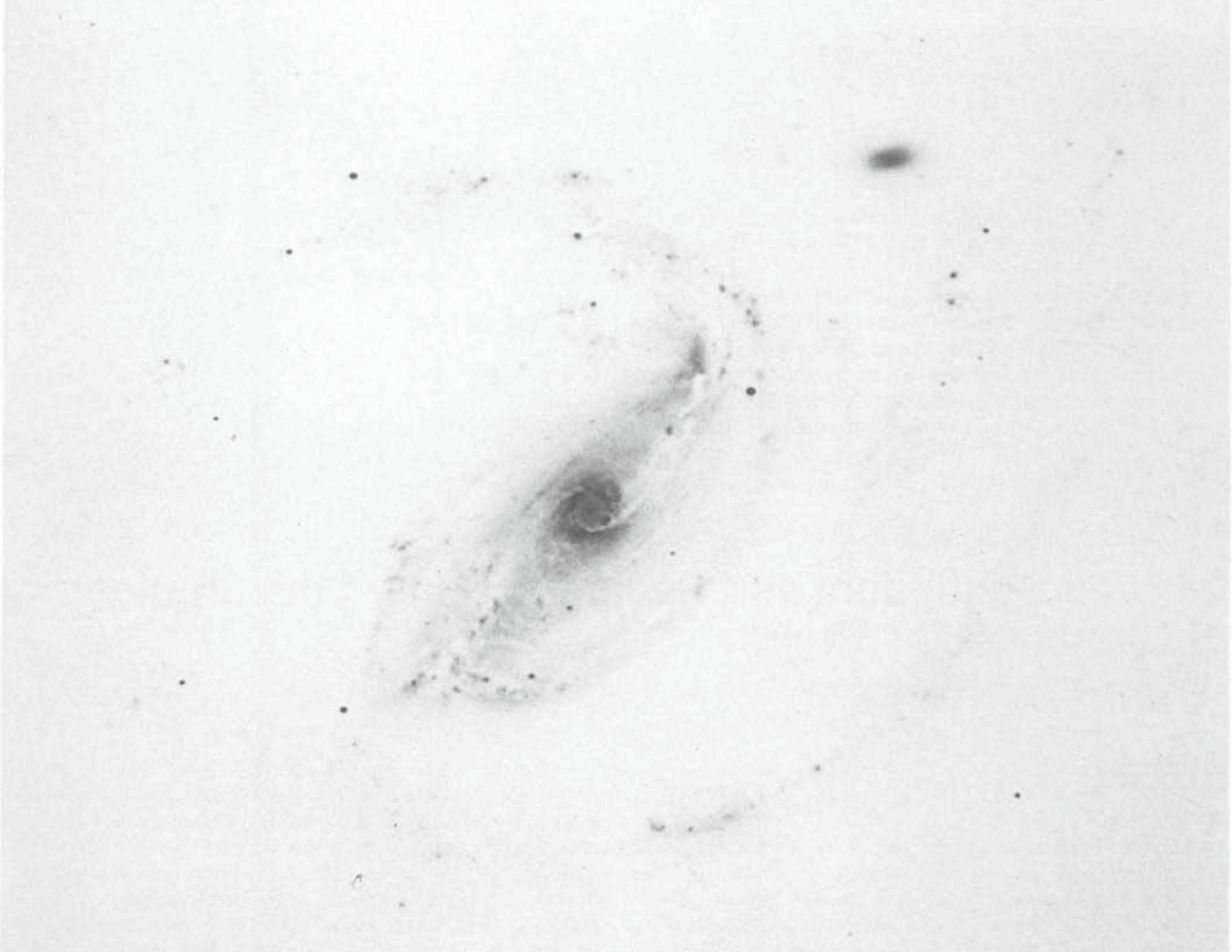


Fig. 1: *This image of the peculiar galaxy NGC 1097 (≡ ARP 77) is an enlargement of the third plate obtained during the commissioning time of the 2.2 m telescope on the night of September 30, 1983. A IIa-O emulsion was used, without filter, and the exposure time was 40 minutes. The star images are slightly elongated because of a field rotation around the guide star, caused by the fact that the polar axis had not yet been properly adjusted. Nevertheless, the excellent optical quality of the telescope (80 % of the light inside 0.4 arcesec) and a good seeing of about 0.7 arcsec, gave a superb view of this Arp galaxy where "the material of arm seems to flow around the companion" and a ring of HII regions surrounds a star-like nucleus.*

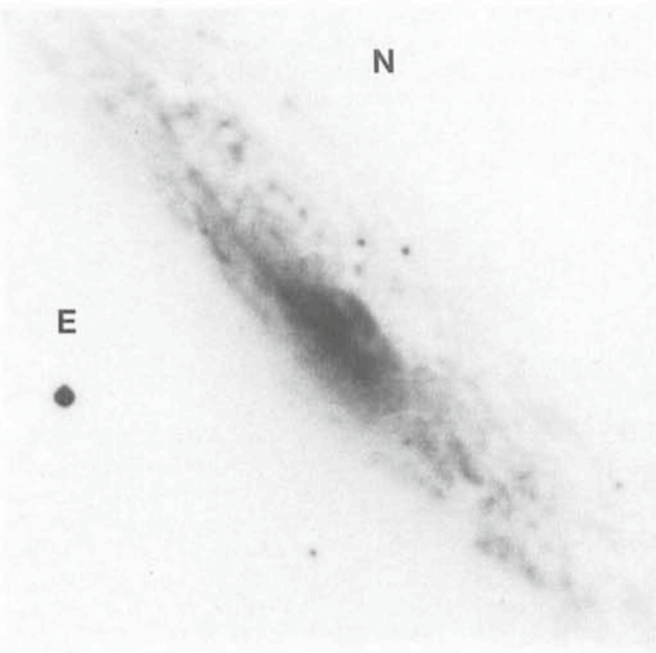


Fig. 2: *The Sc galaxy NGC 1448. The star 25″ E, 5″ S of the nucleus is the recently discovered supernova (IAU Circ. 3877, 3878). This is a CCD picture obtained on October 27/28, 1983, by O.-G. Richter and H. Pedersen with the 2.2 m telescope. The seeing was ~ 0″.7. The field is ~ 60″ square, the pixel size is 0″.36.*

in a photographic mode. The seeing was for the most part better than 1 arcsec and all instruments seemed to perform at the expected levels.

At the present stage we are working towards the final adjustments in order to make use of all automatisms foreseen for the next observing period. We have good reason to believe that the telescope will be fully operational on January 1, 1984, as planned, and that European astronomers will then be able to take full advantage of this powerful new telescope in Chile.

PERSONNEL MOVEMENTS

STAFF

Arrivals

Europe

GIORDANO, Paul (F), Optical Technician, 1.11.1983
REISS, Roland (D), Electronics Engineer, 21.11.1983
JENSEN, Bjarne (DK), Electronics Engineer, 1.1.1984
LOPRIORE, Sergio (I), Mechanical Engineer, 16.1.1984
GROTE, Rainer (CH), Project-Draughtsman, 1.3.1984

Chile

LINDGREN, Harri (S), Astronomer, 1.10.1983
URQUIETA, Arturo (USA), Senior Optical Technician, 1.10.1983
KAABERGER, Ulf (S), Electro-mechanical Engineer, 16.10.1983
LE SAUX, Paul (F), Instrumentation Engineer, 8.11.1983

Departures

Europe

KAZIMIERZAK, Bohumil (B), Mechanical Engineer, 29.2.1984

Chile

MULLER, André (NL), Senior Astronomer, 30.9.1983

FELLOWS

Arrivals

Europe

SURDEJ, Jean (B), 1.10.1983
ANGEBAULT, Louis (F), 1.1.1984
JÖRSÄTER, Steven (S), 16.1.1984

Chile

CHALABAEV, Almas (F), 1.3.1984

Departures

Europe

KOTANYI, Christopher (B), 30.11.1983

ASSOCIATES

Departures

Chile

GREGORY, Thomas (USA), 22.11.1983

Infrared Continuum and Radio Molecular Line Studies of Circumstellar Shells

Nguyen-Q-Rieu, N. Epchtein and T. Le Bertre, Observatoire de Meudon

Introduction

Long-period variables radiate most of their energy in the near and mid-infrared regions. The energy distribution of Mira variables peaks around 2 μm and the well known infrared source IRC+10216 is very bright between 2 and 20 μm. Many late-type stars are not seen at optical wavelengths but appear as strong infrared objects. Re-emission of stellar radiation by warm circumstellar grains is responsible for the infrared continuum flux. Both visible and unidentified infrared cool stars also emit radio molecular lines which are excited by collision with molecular hydrogen or by infrared radiation. Combined infrared and radio observations are therefore of great interest to determine molecular excitation processes.

Late-type stars are characterized by the mass-loss phenomenon. Matter is continuously expelled from the star through a combination of mechanisms such as shock heating and radiation pressure on grains. This can result in a stratification of the circumstellar shell, and molecular line emission serves as probes of physical conditions in different layers. In particular, SiO maser emission (rotation lines in ground and excited vibrational states) and infrared vibration-rotation molecular lines which are excited in extreme conditions, i.e. high gas density and temperature, arise near the stellar photosphere. By contrast, millimetre thermal emission of CO and linear carbon chain molecules, the cyanopolyynes $HC_{2n+1}N$, takes place in the stellar envelope at about 10 to 10^3 stellar radii (Fig. 1). Different shell layers can be sampled by observing appropriate molecular transitions.

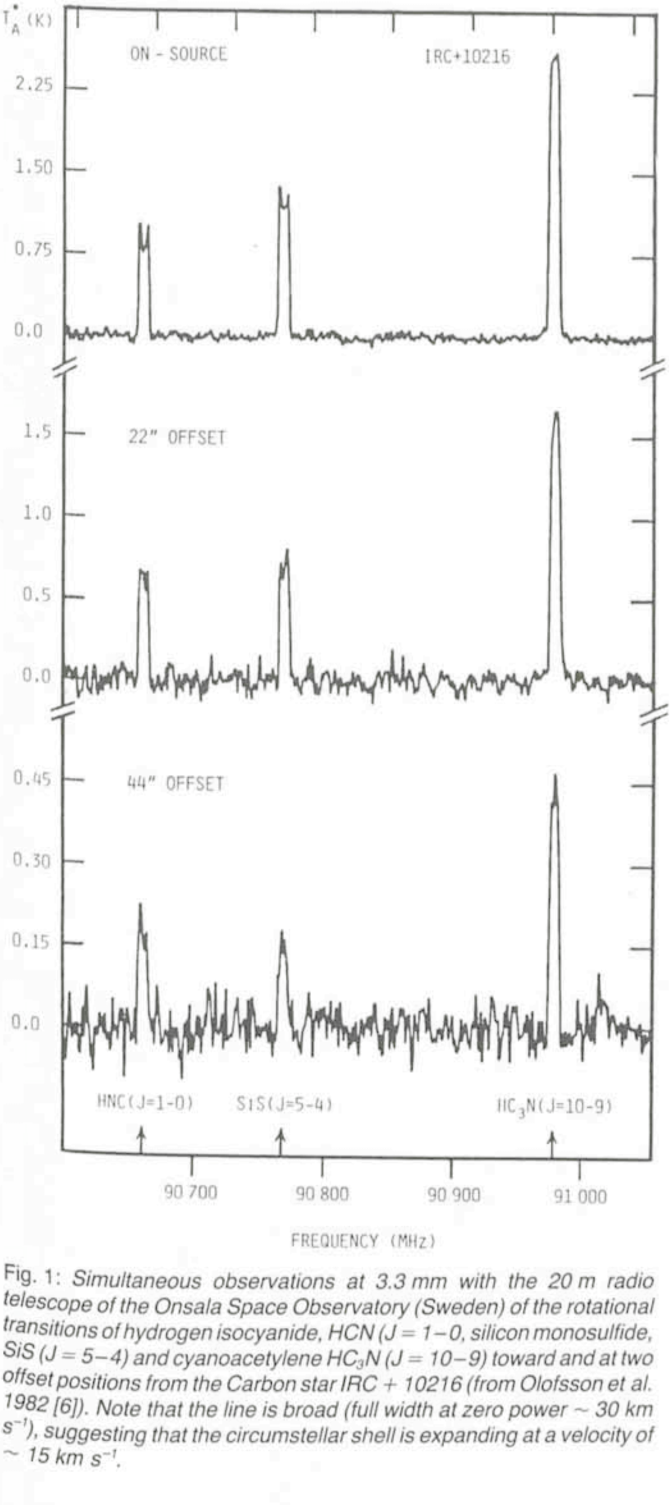


Fig. 1: *Simultaneous observations at 3.3 mm with the 20 m radio telescope of the Onsala Space Observatory (Sweden) of the rotational transitions of hydrogen isocyanide, HCN (J = 1–0, silicon monosulfide, SiS (J = 5–4) and cyanoacetylene HC_3N (J = 10–9) toward and at two offset positions from the Carbon star IRC + 10216 (from Olofsson et al. 1982 [6]). Note that the line is broad (full width at zero power ~ 30 km s^{-1}), suggesting that the circumstellar shell is expanding at a velocity of ~ 15 km s^{-1}.*

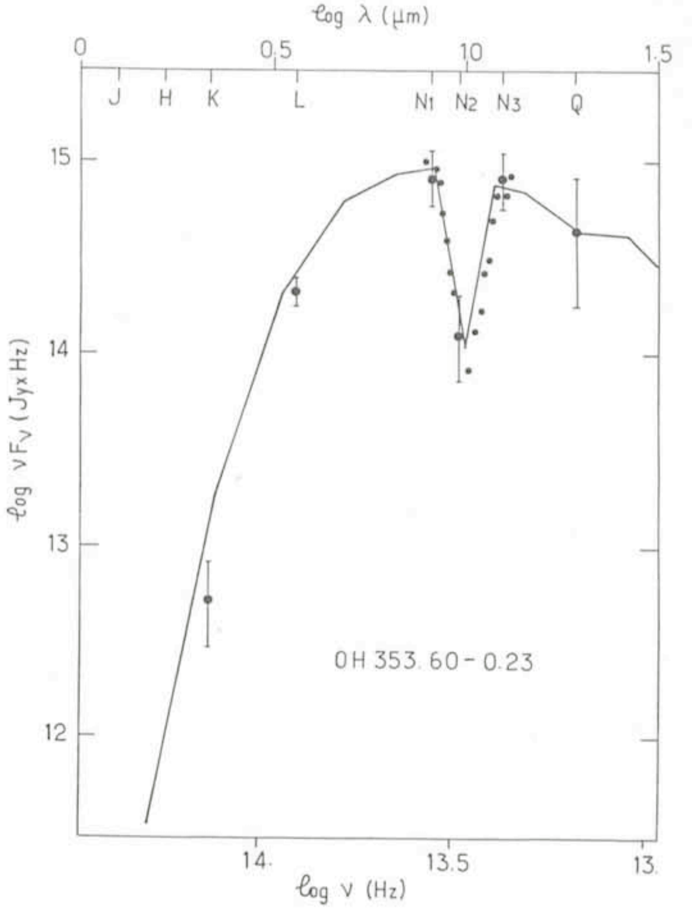


Fig. 2: *Infrared spectrum observed at La Silla of the OH maser source OH 353.60–0.23. The solid curve is derived from radiative transfer calculations (see text) and corresponds to the best fit to the observational data (filled circles). Data (small dots) in the silicate dip (~ 10 μm) were obtained with a higher resolution, λ/Δ λ~ 50.*

Infrared Continuum

We have performed infrared photometric and spectrophotometric observations between 1 and 10 μm in a number of late-type stars, using the 1 m and 3.6 m ESO telescopes at La Silla. The selected objects encompass a variety of microwave characteristics, from strong OH, H_2O and SiO masers (oxygen-rich stars) to weak CO, HCN and cyanopolyyne thermal emission sources (carbon-rich stars). As an illustration, we discuss two cases: the OH maser, OH 353.60–0.23, and the thermal molecular line emitter, IRC+10401.

The infrared counterpart of the OH maser, OH 353.60–0.23, has been detected by Epchtein and Nguyen-Q-Rieu (1) during a search for infrared emission from maser sources in the southern galactic plane, at La Silla. Fig. 2 shows the energy distribution in the near and mid-infrared region (2). The strong dip around 10 μm corresponds to the silicate feature which is the signature of an oxygen-rich star.

IRC+10401 is one of the reddest cool stars with a colour index J–K = 5. There is no evidence of any silicate feature in the spectrum obtained at La Silla (Fig. 3), suggesting that this source is a carbon star.

The circumstellar shell of both sources is so thick that the central star is barely visible.

Molecular Line Emission

OH emission from OH 353.60–0.23 has been detected by Caswell et al. (3). The 1612 MHz line (one of the 4 OH hyperfine transitions in the Λ- doublet of the ground state) is inverted and corresponds to a maser spectrum with two narrow spikes at the wings. These maser peaks arise from the material confined in a narrow double cone whose apex is the central star and whose axis is aligned along the line of sight where the amplification is maximum (4).

IRC+10401 is not an OH maser source, but exhibits thermal emission. We have detected, in collaboration with Olofsson and Johansson (Onsala Space Observatory), thermal HCN and CO line emission in the millimetre wavelength, using the Onsala (Sweden) 20 m radio telescope (6). The HCN (ground-state rotational transition J=1–0) at 3.4 mm is very broad (full

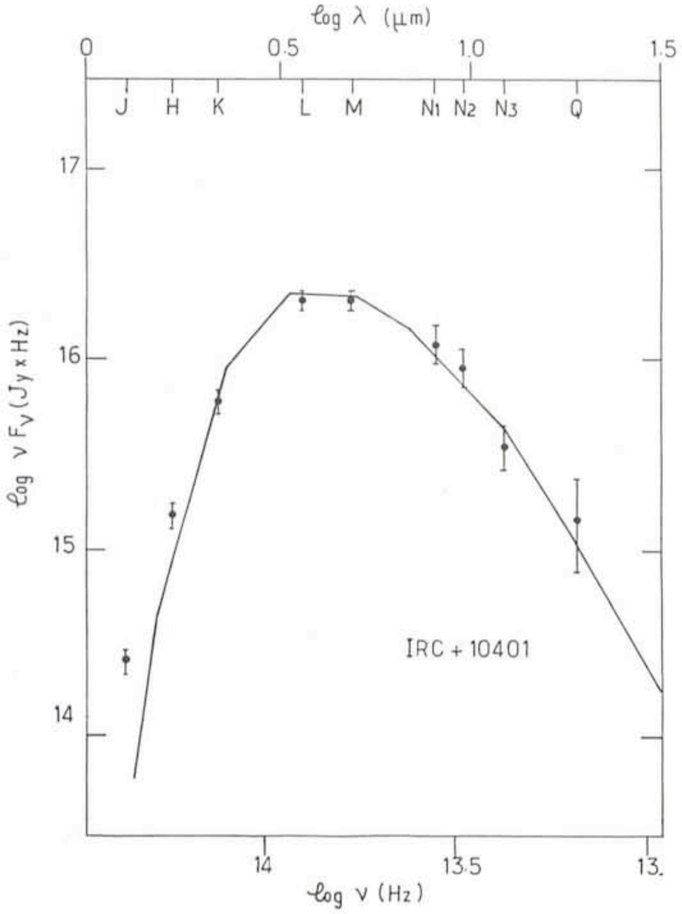


Fig. 3: *Infrared spectrum observed at La Silla of IRC + 10401, an unidentified infrared source, which emits thermal molecular line emission in the millimetre range. The legends are the same as in Fig. 2. No silicate feature is detected.*

width at zero power ~ 80 km s^{-1}), suggesting that the circumstellar shell is expanding at a velocity ~ 40 km s^{-1}, which is approximately equal to half of the linewidth. However, the spectrum can be affected by the presence of blended HCN quadrupole components. The expansion velocity can therefore be slightly smaller.

Shell Parameters

We derive the shell parameters by performing radiative transfer calculations similar to those developed by Leung (5). We assume that the shell is expanding uniformly and the stellar temperature is 2,000–2,500 K. With reasonable assumption on grain characteristics (dirty silicate or graphite), distance (usually kinematic) and gas to dust ratio (~ 100), the fit of the calculated emergent IR spectrum to the observed data gives information on the shell physical conditions. For OH 353.60–0.23, we derive a stellar luminosity, $L_* \sim 8\times10^4 L_\odot$, a dust mass-loss rate, $\dot{M} \sim 3\times10^{-6} M_\odot$/yr. The gas density which is assumed to vary as $1/r^2$ is ~ 10^8 cm^{-3} in the inner region. This quantity as well as the infrared flux are very important in the determination of the excitation of the molecular lines (2). Whereas the optically thick CO line is excited by collision with H_2, the OH and HCN lines are excited by radiation. In the case of HCN, the molecules are excited from the ground-state to higher vibrational states through the absorption of infrared photons. Subsequent cascades will populate high-lying rotational levels of the ground vibrational state, leading to the emission of millimetre lines.

Conclusion

Infrared and radio molecular line observations provide invaluable information not only for the investigation of the shell parameters but also for the understanding of the physical processes in the circumstellar material, namely the excitation of molecular lines. Late-type stars undergo periodic intensity variation in both infrared continuum and infrared and radio molecular line emission. Molecular species, such as SiO, which have high dipole moment (μ_{SiO}~3 Debye) are very sensitive to radiation. The change of the line shape as a function of the stellar phase (period of infrared light curve ~ 300–700 days) merely reflects the variation of the stellar flux. Time monitoring studies in the infrared and millimetre molecular line emission is thus of great importance to elucidating the interaction through the mass-loss phenomenon between the innermost and outer parts of the circumstellar envelope.

References

(1) Epchtein N., and Nguyen-Q-Rieu, 1982, *Astronomy and Astrophysics* **107,** 229.
(2) Le Bertre T., Epchtein N., Gispert R., Nguyen-Q-Rieu and Truong-Bach, *Astronomy and Astrophysics,* in press.
(3) Caswell J. L., Milne D. K., and Wellington K. J., 1981, *M.N.R.A.S.* **195,** 89.
(4) Nguyen-Q-Rieu, Laury-Micoulaut C., Winnberg A., and Schultz G. V., 1979, *Astronomy and Astrophysics* **75,** 351.
(5) Leung C. M., 1975, *Astrophysical Journal* **199,** 340.
(6) Olofsson H., Johansson L. E. B., Hjalmarson A, Nguyen-Quang-Rieu, 1982; *Astronomy and Astrophysics* **107,** 128.

"To UGC 6697. – When you reach the point where all reasonable assumptions seem not to fit with the observed facts: the rotation curve looks like that of a frisbee, the spectral index like that of a fire-work and the morphology seems the one of a Havana cigar . . . then it is perhaps better to take a few days off and look for radical alternatives." (Painting by Beffo Gavazzi.)

BD Pavonis: Nova, Dwarf Nova, or . . . ?

H. Barwig, Universitäts-Sternwarte München

Among all kinds of stars probably the most spectacular ones are novae, which suddenly increase their brightness up to more than a million times and then fade again in timescales of months or years to their original faintness. In spite of this outstanding, dramatic behaviour these objects have many properties in common with other so-called cataclysmic variables (CV).

From numerous observational and theoretical work we have learned that these particular stars are very close binaries, some with orbital dimensions of the order of our sun's diameter. The systems consist of a late-type secondary filling its Roche lobe, and a very compact hot primary, which is supposed to be a white dwarf or even a neutron star. Matter flowing from the expanding cooler companion towards the primary normally cannot reach its surface directly due to its excess angular momentum. It is therefore stored first in a rotating accretion disk. An important subgroup of the CVs are the dwarf novae which in contrary to novae show quasiperiodic outbursts on a timescale of days with much smaller amplitudes.

R. Schoembs and I learned in the course of an observing programme started three years ago that a nova can attract attention not only during its discovery but even fifty years later. Part of our observations aimed at the investigation of relatively unknown old novae in the southern hemisphere. About 85 such objects, for which only fragmentary data exist, had been reported by Payne-Gaposchkin ("The Galactic Novae", 1957). Twenty-two of them were selected according to the indicated brightness and the reliability of finding charts that could be found in the literature.

In order to use the allotted observing time most efficiently, we started with taking image-tube spectra at the 1.5 m ESO telescope in June, 1980, to decide which candidates should be observed in more detail and which were even no longer detectable. For a rough brightness estimation the density of each 20-min. exposure was taken. Every two hours a plate containing the spectra of 6 different objects was developed. Probably only a spectroscopist can imagine our tension whenever the exposures were ready for a quick, first inspection in the darkroom.

One of the spectra, that of BD Pav, attracted our particular interest. It showed broad, strong, double emission lines on a well-exposed continuum (Fig. 1) suggesting a visual brightness around 15th magnitude. We were looking for just such spectra, since the doubling of lines, originating from the accretion disk, normally indicates binaries with high orbital inclination which favours the occurrence of eclipse phenomena and considerable radial velocity variations which could provide important information about the binary system.

Payne-Gaposchkin gives a brief note about BD Pav: The star has been discovered by C. D. Boyd (*Harv. Ann.* **90,** 248, 1939) on two plates taken in 1934. Within a time interval of less than 4 days the star has brightened from invisibility to 12$^{\mathrm{m}}$4. 20$^{\mathrm{d}}$ later it had become invisible again, i.e. fainter than 16$^{\mathrm{m}}$5. Due to the short timescale of its disappearance and the unknown minimum brightness the star has been classified as a faint, fast nova.

Had BD Pav now brightened again? Is the classification as a nova correct at all? – The possibility of a small outburst amplitude already raised some doubt.

This was enough to monitor this object photometrically during the following nights. Fast photometry with a time resolution of 3 s was performed using the 1 m ESO and the 1.5 m Danish telescope, partly operating both telescopes simultaneously in the visual and near infrared wavelength regions. Soon after starting the measurements, short-time variations ("flickering") became visible, a characteristic property of most CVs.

More exciting, however, were quasi-periodic light variations, which occurred on a timescale of about one hour and sudden deep depressions of the light-curve that looked like eclipse features (Fig. 2). Since that night was by no means photometric and even some clouds could be recognized, we were not able

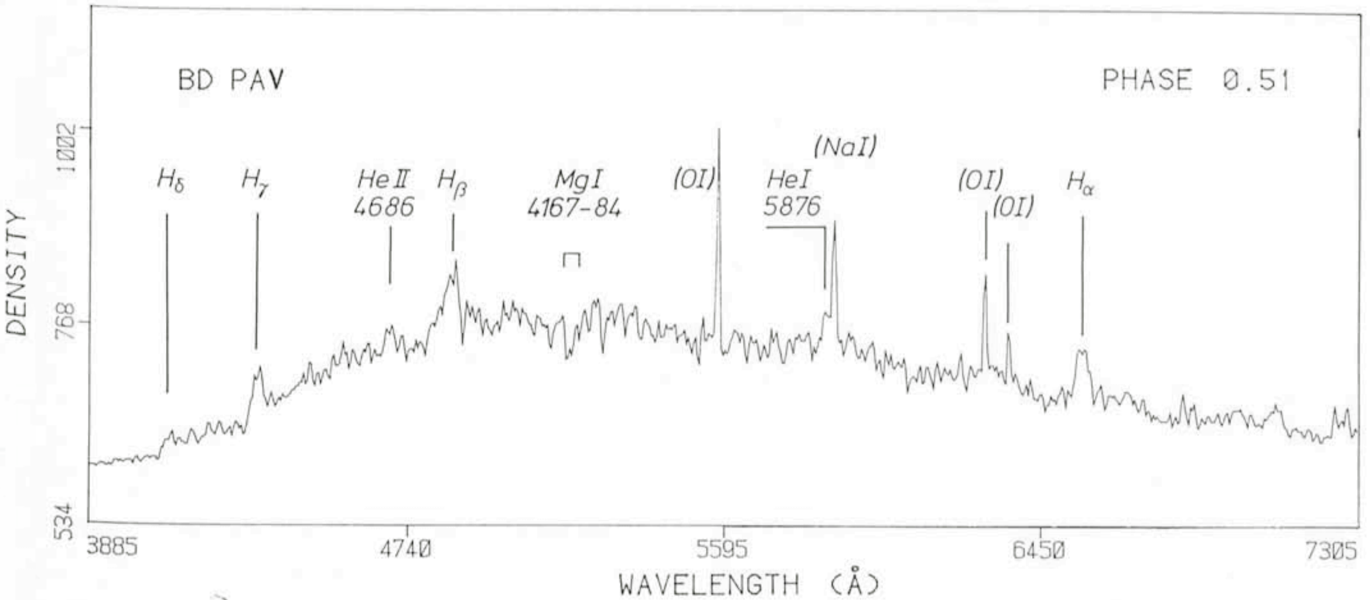


Fig. 1: *Single image-tube spectrum of BD Pav (with superimposed atmospheric emissions) obtained with the Boller and Chivens spectrograph at the ESO 1.5 m telescope. Dispersion: 114 Å/mm, exposure time: 20 min.*

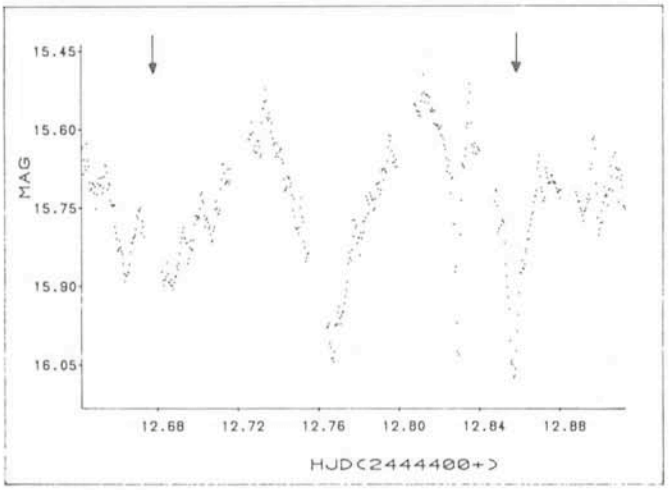


Fig. 2: *First light-curve (in white light) of BD Pav recorded in 1980 at the Danish 1.5 m telescope. The timings of primary eclipse, derived from the 1981 observations, are marked by arrows. The measurements are strongly affected by changing atmospheric transparency as can be seen by comparison with Fig. 3.*

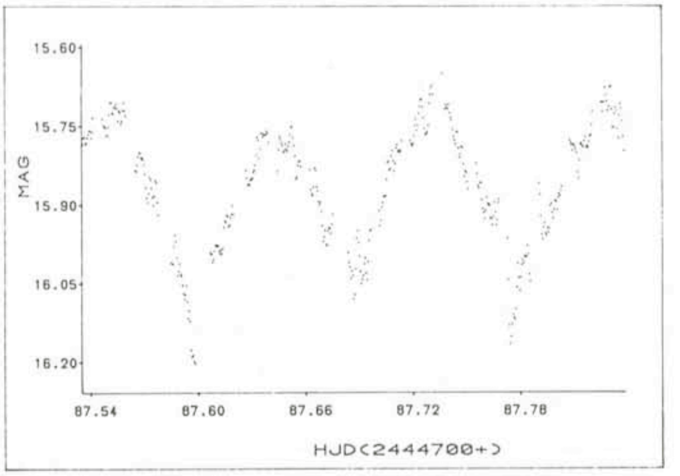


Fig. 3: *B light-curve of BD Pav, obtained in 1981, showing the double hump between two successive primary minima. Interruptions are due to comparison star monitoring.*

to distinguish between intrinsic or atmospheric variations by that time. Bad weather conditions closed down observation for the remaining observing time. So we had to learn this way one of the possible reasons why this object remained almost unobserved: The sky position of BD Pav ($\alpha = 18^h39^m$, $\delta = -57°35'$) makes it observable only during winter time, when the number of clear nights are considerably reduced.

A second observing run in 1981 was more successful. Five clear nights at the 1 m ESO telescope could be used for high-speed photometry, covering sequentially the wavelength region from ultraviolet to the near infrared. Furthermore 13 successive spectra were taken at the 1.5 m ESO telescope at a dispersion of 114 Å/mm.

Periodic light variations, already suggested one year before could now be clearly confirmed. The mean brightness of $m_v = 15.5$ had not changed. If we accept this value for the minimum brightness of BD Pav, the amplitude of the eruption in 1934 and its short timescale indicates a dwarf nova outburst. Since no other eruptions were reported, a long outburst cycle, however, has to be assumed.

A typical light-curve of BD Pav is shown in Fig. 3. It is characterized by a double hump ($\Delta m = .5$) and a sharp eclipse feature (primary minimum) repeating with strict phase stability. From the observed timings of this minimum an orbital period of $4^h18.2^m$ was derived. Whereas this short period is usual for CVs the shape of the light-curve is by no means usual. (A refined average light-curve can be found in a paper by Barwig, H., Schoembs, R.: 1983, *Astronomy and Astrophysics,* **124,** 287). Normally only a single hump is observed in the visual light-curve of CVs with suitable orbital inclination. It can be explained by the changing aspect of a hot spot on the accretion disk. In systems where the inclination is sufficiently high, an obscuration of this spot and of the primary or inner disk region can occur, yielding a sharp, short-lasting depression on the trailing edge of the hump. As opposed to this, BD Pav shows the eclipse centred in the middle between two humps.

Another surprising property of BD Pav is its red colour ($B-V = 0.^m63$) which corresponds to a cool G star like our sun. CVs with short periods usually show a very blue continuum caused by radiation from the spot-disk-primary configuration. Only in systems with orbital periods exceeding 6^h does the cool red secondary gain more influence in visual light due to its larger dimension.

What kind of star is BD Pav in fact? Sometimes we even doubted its classification as a CV.

However, beside the puzzling red colour and the strange shape of its light-curve this star certainly exhibits a lot of properties characteristic of CVs: The outburst, the short orbital period, the flickering activity, an emission-line spectrum and a short deep eclipse.

In order to get out of this dilemma, we might assume that BD Pav contains a luminous evolved secondary whose radiation significantly contributes to the visual system brightness. In this case the companion star could produce the observed "ellipsoidal variable" type light-curve as a result of its tidal distortion. Similar light-curves have been recorded for normal short period CVs when observed at infrared wavelengths, where radiation from the cool main-sequence secondary becomes dominant (Bailey et al. 1981, *Mon. Not. R. Astr. Soc.,* **196,** 121).

On the other hand one might expect that BD Pav should behave more like a normal CV at shorter wavelengths. Indeed, a phase shift of the ultraviolet light-curve relative to the visual curve is observed. Hence the eclipse feature which occurs at the same orbital phase in all colours appears now at a position where it is found usually for CVs.

From the theoretical point of view (H. Ritter, 1983, in: Proceedings of IAU Coll. No. 72, 257) the secondary of a cataclysmic binary could in fact be significantly evolved depending on the mass ratio of its progenitor system. However, no such system has ever been observed so far.

For a further investigation of BD Pav, a new observational programme has been proposed last year. Spectroscopy and simultaneous multicolour photometry should be performed in order to separate the radiation of the primary-disk-configuration and of the secondary.

Extreme weather conditions in July 1983 (i.e. heavy snowfall on La Silla lasting for days) permitted only one single, not even photometric night of observation at the 90 cm Dutch telescope used for 5-colour measurements with the Walraven photometer. BD Pav again could successfully hide away.

New Edition of ESO Users Manual

Please note that a new edition of the ESO Users Manual (March 1983) has recently been published and distributed.

The distribution is in principle limited to astronomical institutes and libraries; a very limited number of copies is still available.

Optical Identification of the Transient X-ray Source 4U1543–47

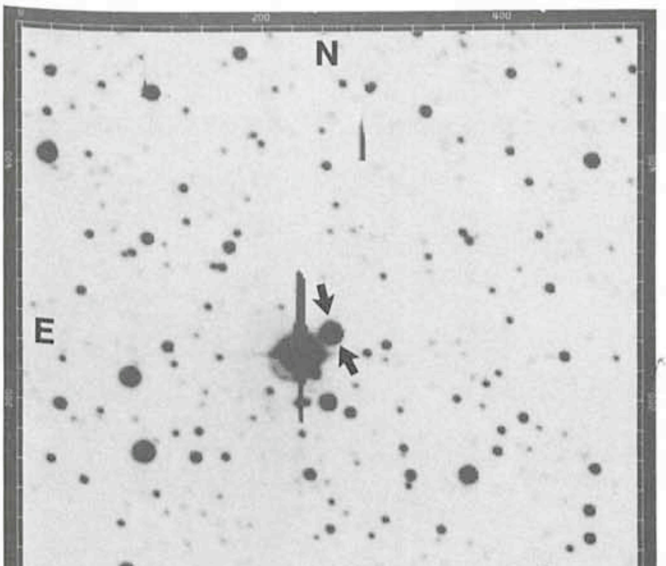
H. Pedersen, ESO

Since the decay of the highly successful X-ray observatory on board the "Einstein" satellite, things have been relatively quiet concerning discoveries on the X-ray sky. For some time, the scene was dominated by the tiny Japanese satellite Hakucho. This spacecraft carried no imaging detectors, but turned out to be very useful for the study of already known, relatively bright sources. At ESO, we used much observing time simultaneously with Hakucho in an attempt to learn more about the so-called X-ray burst sources (1). Recently, two more X-ray satellites have been launched: the second Japanese satellite, TENMA, and the European EXOSAT.

Most of the observations with these satellites are planned in advance, but, as is the case with ground-based observations, the temporary appearance of a new celestial object may justify a change of schedule. This is what happened on August 18, 1983, when the transient source monitor on board TENMA detected a bright, new X-ray source near the border between the southern constellations Lupus and Norma. Three days later the source had reached half the brightness of Sco X–1, which may be called the "Sirius" of the X-ray sky. At La Silla, we were immediately alerted by telex in order that we could try to identify the source optically, but during just those days, odds were against any optical work. Full moon was approaching, and the Schmidt telescope was out of operation because of technical work. Dr. Tanaka, from the TENMA team, had, however, remarked that the new source appeared very close to the position of a bright X-ray transient which had been seen from July 1971 till September 1972 by the Uhuru satellite. This source, called 4U1543–47 (2), had never been identified optically. We immediately checked our CCD data bank for pictures of the former transient position. Indeed, CCD pictures had been taken in July 1981 during the installation period of the CCD camera at the 1.5 m Danish telescope. Prior analysis of these images (which were taken in three colours) had shown no object of conspicuous colours. The images were checked once more, but with the same result. The location of the old transient was, however, not known to great accuracy, and it could, indeed, be outside the area covered by the CCD.

The operation team of the EXOSAT satellite had, of course, also been alerted by the Japanese discovery. The first, crude analysis of observations from August 28 resulted in a position which was well outside the old error box, although still, in itself, quite large, 30″ maximum error radius (3). This readily gave a good reason why our old CCD pictures had not shown anything interesting. Still, the two positions are so close that the two transients must be identical.

Finally, on the last night of the month we obtained a Schmidt plate of the area. The photograph was taken in red light in order to compare it with a similar plate from the ESO Survey of the Southern Sky. The classical method would now be to "blink" both exposures, but we chose first to put them on top of each other. Shifting one slightly with respect to the other, we did, in fact, see what we had hoped for: a star which had increased in brightness. The change was only modest, at most a factor of 2.5, but still interesting as the star was located near the middle of the error circle quoted by the EXOSAT team (Fig. 1 is a finding chart of this star).



4U 1543-47

Fig. 1: *Finding chart of the optical counterpart of 4U1543–47 from a CCD frame obtained with the 1.5 m Danish telescope. The field is apparently 2 arc minutes square.*

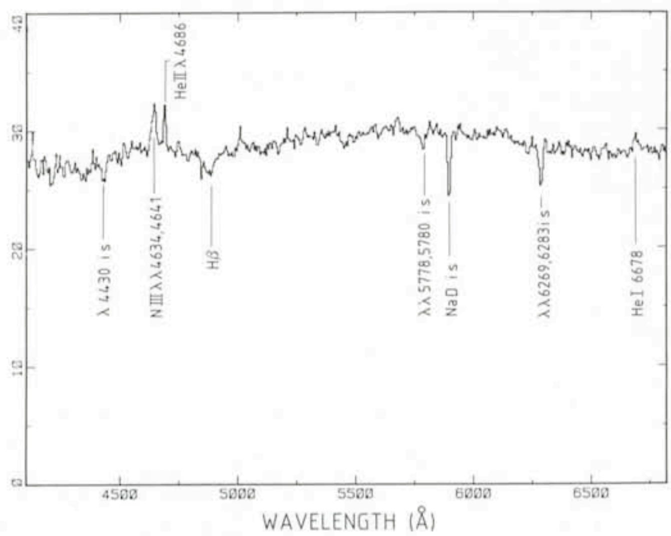


Fig. 2: *Spectrum of the optical counterpart of 4U1543–47 obtained on the evening of September 2, 1983 with the Image Dissector Scanner and the Boller and Chivens spectrograph attached to the Cassegrain focus of the 3.6 m telescope. The dispersion was 171 Å/mm^{-1}. Exposure time: 60 min. The emission line He II λ 4686 and the blend N III λλ 4634, 4631 are clearly visible, leaving no doubt as to the identification with the X-ray source. Several interstellar absorption features are present with a relatively large equivalent width, showing that this star is relatively distant. This spectrum is very similar to the one of other transient X-ray sources, e.g. A0620–00 (5).*

The same night was the first in a new CCD run at the 1.5 m Danish telescope and we managed to squeeze the object in. Although low in the west at the start of the night, the pictures allowed a crude measurement of the brightness and colour of the candidate from the Schmidt plate. Observations from this night and from the two following are consistent with a constant V = 14.9, B–V =0.6. The object is thus not a very conspicuous one with respect to either brightness or colour. The final confirmation would have to come from spectroscopy. Luckily, the 3.6 m telescope was assigned for low-dispersion spectroscopy during the same nights. Mira and Philippe Véron were equipped with a finding chart and were able, shortly after the start of the night of September 1/2, to confirm the discovery. The candidate showed a spectrum rather typical for X-ray transients, the most characteristic feature being emission lines due to nitrogen and helium. Later spectra, by the Vérons, by Joergensen, and by Pakull, have added much weight to the observations, and may even be used for studying the variability of certain features. The strength of some interstellar absorption lines is indicative of the distance of the object, probably more than 1 kpc (~ 3000 light-years) (Fig. 2).

By the middle of October, Dr. Blissett, of the EXOSAT team, reported that the X-ray position had been refined so that the maximum error now is 10". The new position is, in fact, only 4" from that of the optical counterpart as measured with the pointing facility of the 1.5 m Danish telescope (4).

References

(1) van Paradijs, J. 1981, *The Messenger* **23,** 1.
(2) Forman, W. et al. 1978, *Astrophysical Journal Supplement Series,* **38,** 357.
(3) Blissett, R. J. 1983, IAU Circular No. 3858.
(4) Pedersen, H., Véron, M., Véron, P., and Schuster, H.-E. 1983, IAU Circular No. 3858.
(5) Oke, J. B., and Greenstein, J. L. 1977, *Astrophysical Journal* **211,** 872.

Colour Pictures with a CCD Camera

M.-P. Véron-Cetty and P. Véron, ESO

The 1.5 m Danish telescope at La Silla has been used to photograph a number of galaxies with a CCD camera (1) through three different filters: blue (Johnson B), red and infrared (Gunn r (L) and z). The images have been reduced with the ESO image processing system IHAP and then transferred to the VAX computer to use DICOMED, the high quality hard copy device which produces colour slides. These photographs are in real but not natural colours in the sense that instead of using blue, green and red images, we have used blue, red and infrared. The colour balance is arbitrary but the same for all pictures, except #2. The seeing was 1.2 to 1.5 arcsec. In all cases, north is at the top, east to the left.

Fig. 1: NGC 1068. This is the prototype of Seyfert 2 galaxies. The picture shows an overexposed nuclear region, the red nuclear bulge and a ring of blue knots, hot stars and H II regions. To the NE and SW of the nucleus, some kinds of reddish filamentary structures emerge in the general direction of the radio structure (3). (Field size 47 × 47 arcsec).

Fig. 2: NGC 1068. In contrast to all other pictures taken here, this was produced using an image taken with a 250 Å bandwidth filter centred on 5500 Å, avoiding all emission lines, the z image which also avoids emission lines, and a narrow band ($\Delta\lambda$ = 20 Å) filter centred on the very strong [OIII] λ 5007 Å emission line. The nuclear region is again overexposed. The emission line region appears green, extending towards the NE. Narrow band pictures (4), (5) have previously revealed this emission cloud. The scale is the same as for the preceding image.

Fig. 3: NGC 1808. This is one of the rare galaxies with nuclear hot spots (6). Three primary hot spots connected by high surface brightness filaments have been reported (7). Our picture indeed shows a star-like nucleus and two blue "hot spots" to the SE and NW of the nucleus with reddish filaments which may not connect the nucleus to the hot spots. Spectra obtained with the IDS and the Boller and Chivens spectrograph at the ESO 3.6 m telescope with a 4 × 4 arcsec aperture show that the strong Hα and [NII] emission lines have a complex profile, suggesting the superposition of a normal H II region and a Seyfert-like nebulosity similar to that observed in the nucleus of the SBb galaxy NGC 7496 (8). It is therefore very likely that NGC 1808 has a Seyfert 2 nucleus; this galaxy is associated with the radio source PKS 0505–375 which has received very little attention. The red filamentary structure could be associated with the Seyfert phenomenon rather than with the hot spots. This galaxy clearly deserves more observations (field size: 47 × 47 arcsec).

Fig. 4: NGC 7177. Sab galaxy. The bright red bulge is partly obscured on the SE quadrant by dust. Faint blue arms can be seen (field size: 47 × 47 arcsec).

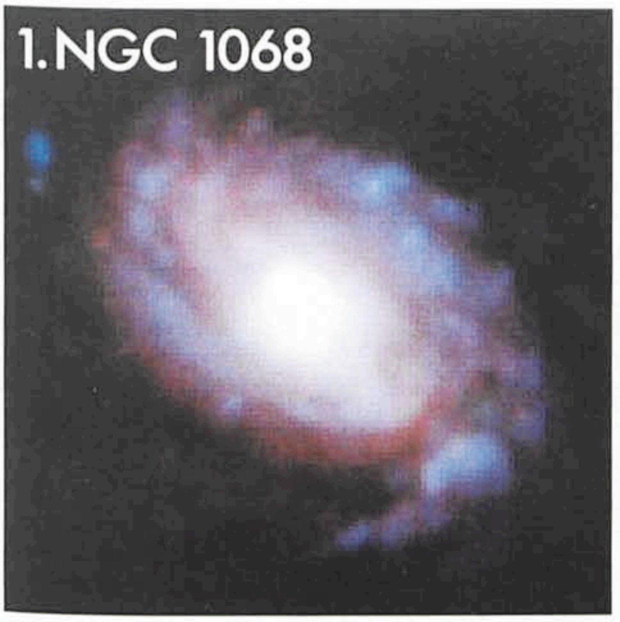
Fig. 5: NGC 289. This late type (SBbc) galaxy has quite a conspicuous nucleus (with very faint emission lines) in a red bulge, partly obscured by dust lanes, and surrounded by blue spiral arms (field size: 104 × 104 arcsec).

Fig. 6: NGC 7496. SBc galaxy. The picture shows well the blue regions of star formation in the arms. The bulge is almost non-existent. A spectrum of the bright nuclear region shows complex emission lines (8) (field size: 47 × 85 arcsec).

Colour pictures are not only attractive, they may also be useful as is best shown by the photograph of the central region of NGC 1808 which makes it possible to sort out the different components.

References

(1) Pedersen, H., and Cullum, M. 1982, *The Messenger* **30,** 26.
(2) Thuan, T. X., and Gunn, J. E. 1976, *Publications of the Astronomical Society of the Pacific* **88,** 543.
(3) Wilson, A. S., and Ulvestad, J. S. 1983, *Astrophysical Journal* **275,** 8.
(4) Bertola, F. 1968, *Astronomical Journal* **73,** 861.
(5) Alloin, D., Laques, P., Pelat, D., and Despiau, R. 1981, *Astronomy and Astrophysics Supplement Series* **43,** 231.
(6) Sersic, J. L., and Pastoriza, M. 1965, *Publications of the Astronomical Society of the Pacific* **77,** 287.
(7) Garrison, R. F., and Walborn, N. R. 1974, *The Journal of the Royal Astronomical Society of Canada* **68,** 117.
(8) Véron, P., Véron, M.-P., Bergeron, J., and Zuiderwijk, E. J. 1981, *Astronomy and Astrophysics* **97,** 71.


1.NGC 1068


2.NGC 1068


3.NGC 1808


4.NGC 7177


5.NGC 289


6.NGC7496

A Search for White Dwarfs in the Solar Neighbourhood

G. Rupprecht and I. Bues, Dr.-Remeis-Sternwarte, Bamberg

Introduction

White dwarf stars represent one of the two final stages of normal stellar evolution. Their degenerate core of a very small mass range ($0.6\ M_\odot \pm 0.2\ M_\odot$) and a radius of $< 1/100\ R_\odot$ is surrounded by a convection zone and an atmosphere with a thickness of several hundred metres. The effective temperatures for the observed objects range from 70,000 K with the colours of O stars down to 4,000 K with the colours of early M stars. This cooling sequence is due to the initial mass and the age of the stars, the coolest objects being several 10^9 years old. For further details about white dwarfs and the evolution leading to their formation see Koester (1982, *The Messenger* No. 28, p 25).

From white dwarf birth rates and cooling theory it is possible to compute number densities expected for various temperature or bolometric magnitude intervals. For hot white dwarfs ($T_{eff} > 12{,}000$ K) observations agree well with predictions (Green 1980, *Astrophysical Journal* **238,** 685), whereas theory predicts more cool white dwarfs ($T_{eff} < 8{,}000$ K) than are actually known (Liebert et al. 1979, *Ap. J.* **233,** 226). According to these authors there should be 11 white dwarfs with M_{bol} between 13^m and 15^m within a distance of 10 pc and north of $\delta = -20°$, but only 8 are known. This is not significant; however, the deficit is more pronounced for stars with $15^m < M_{bol} < 17^m$: instead of 40 only 3 are observed.

Several attempts to find these "missing" white dwarfs focused upon stars with large proper motions, but without much success. So we decided to investigate stars with small proper motions (generally less than 0.″5/year), mpg $< 15^m$, $0 > \delta > -35°$, to look for nearby white dwarfs with tangential velocities < 40 km/s. As sources for our candidates we took the Lowell Observatory GD and G Lists (Giclas, Burnham and Thomas 1980 and 1978, *Lowell Observatory Bulletin* **166** and **164**) because they provide proper motions, photographic magnitudes, colour estimates, precise coordinates and good finding charts.

Photometric Observations

From 1980 to 1983 a total of 173 stars have been observed during 6 observing periods. During the first two seasons the Bochum 61 cm telescope on La Silla was used, in 1980 with the old DC amplification photometer system and in 1981 with the new pulse-counting photometer, which now works completely computer-controlled as does the telescope mounting. This new computer control gave a better internal accuracy of the measurements (typically a few hundredths of a magnitude for stars with $V = 12^m$ to 15^m), thus significantly enhancing the efficiency of the telescope. With the Bochum telescope, observations were carried out in the UBV and Strömgren uvby systems. During the following four observing seasons we used the ESO 1 m telescope for UBVRI and uvby measurements.

Data Analysis

Classification of the stars is done by means of various two-colour diagrams. The classical diagram (Fig. 1) allows recognition of main-sequence stars with spectral types later than about B 3, of hydrogen-rich white dwarfs (DA) and of white dwarfs with helium or continuous spectra (DB or DC). The two crosses high above the black-body line represent white dwarfs with

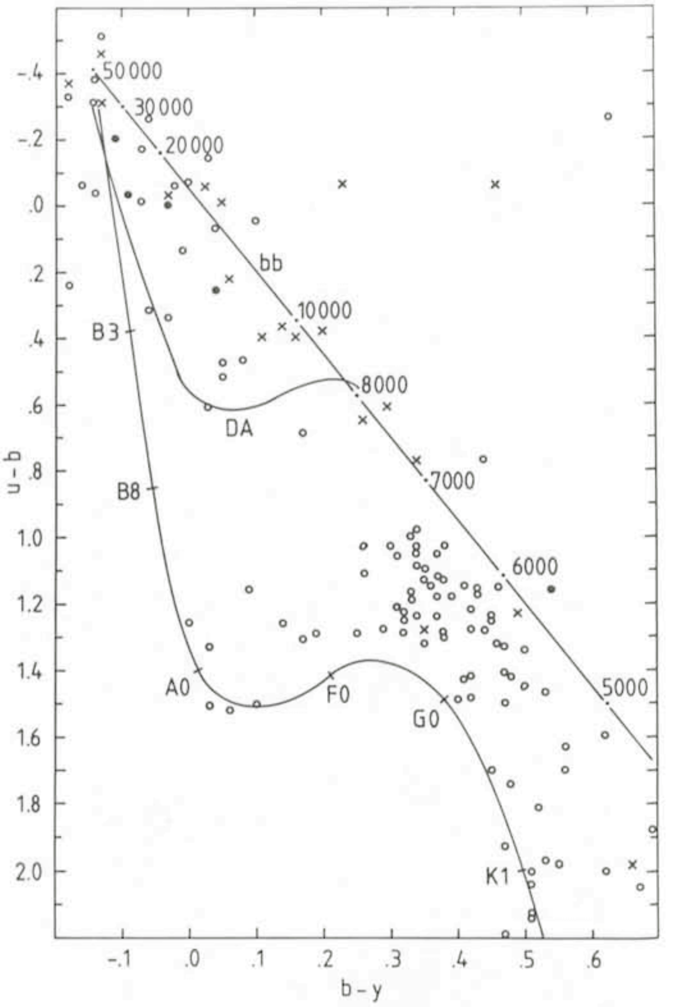


Fig. 1: *Strömgren two-colour diagram (u-b)/(b-y) of stars observed in 1980–1983 with the Bochum 61 cm and ESO 1 m telescopes on La Silla. The black-body line (bb) and the main sequence are indicated. (○) newly classified stars; (●) new observations of known white dwarf stars; (x) already known white dwarfs.*

strong C_2 absorption bands, leading initially to the suggestion that the object observed with similar colours might be a white dwarf of spectral type C_2. However, spectra taken with the ESO 1.52 m telescope (see below) show strong emission lines revealing GD 1339 as a QSO with z = 0.114. At $V_E = 14.^m6$ it is one of the brightest QSOs in the sky.

In the very hot region of the (u-b)/(b-y) diagram, however, it is not possible to separate white dwarfs with $T_{eff} > 50{,}000$ K from subdwarfs and early-type main-sequence stars. The same is true in the very cool region, where white dwarfs of $T_{eff} < 6{,}000$ K can be mixed up with subdwarfs of spectral types sdF, G and K. Both problems can be solved by introducing new two-colour diagrams where the coordinates are taken from different filter systems. Fig. 2 shows the hot end of the (u-b)/(U-V) diagram where a clear separation between the main sequence and the black-body line exists. In this diagram the white dwarfs cluster around the black-body line regardless of their spectral types. The same is true for the (R-I)/(u-b) diagram (Fig. 3).

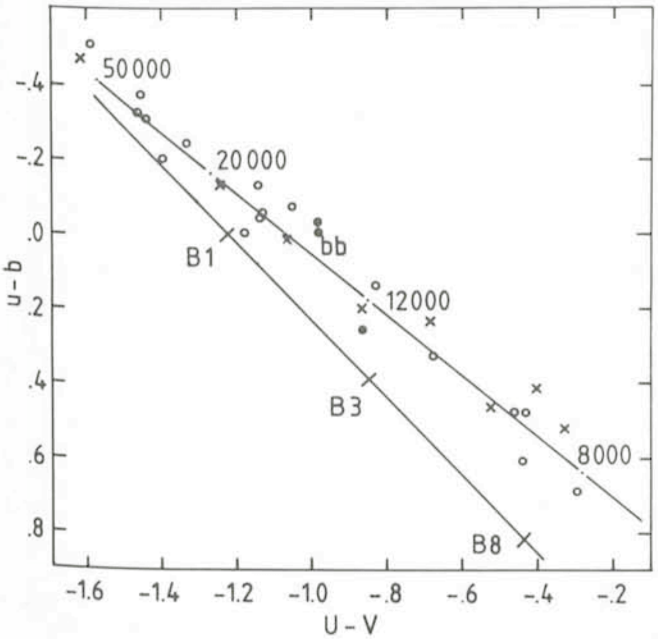


Fig. 2: *Combined two-colour diagram Strömgren (u-b)/Johnson (U-V) for hot stars. Symbols are the same as in Fig. 1.*

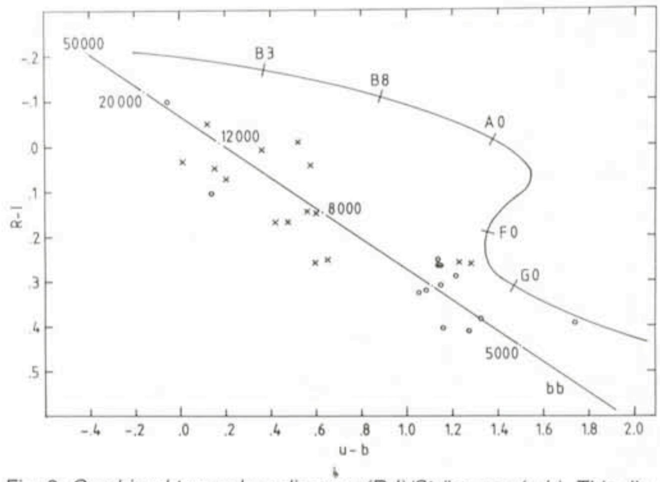


Fig. 3: *Combined two-colour diagram (R-I)/Strömgren (u-b). This diagram allows recognition of cool white dwarf stars. Symbols are the same as in Fig. 1.*

From these and similar two-colour diagrams 46 stars were classified as white dwarfs.

For achieving our goal — to determine the number of white dwarfs in the solar neighbourhood — the distances of our new objects should be known. Various colour-luminosity relations were used two derive photometric parallaxes. Absolute visual magnitudes for cool stars were derived from a M_V/(B-V) relation given by Greenstein (1976, *Astrophysical Journal* **81,** 323), from a linear regression M_V/(b-y) based on Graham's data (1972, *A. J.* **77,** 144) as cited by Green (1980, *Ap. J.* **238,** 685), and from linear regressions M_V/(u-b) and M_V/(R-I) which we calculated for stars with known trigonometric parallaxes. Since only very few hot white dwarfs have measured parallaxes, second order polynomials were fitted to hot hydrogen-rich model atmospheres (Wesemael, Auer, van Horn, Savedoff 1980, *Ap. J. Suppl.* **43,** 159) or to helium-rich (DB) white dwarfs to define again colour-luminosity relations. Distances were then computed from the calculated absolute magnitudes and the observed magnitudes. The resulting spatial distribution (excluding GD 1339) is given in Table 1).

Table 1. Distances of photometrically identified white dwarfs

Distance in parsec	cool white dwarfs	hot white dwarfs
0 – 10	12	0
10 – 20	8	3
20 – 50	1	13
> 50	0	8

Spectroscopic Observations

Although photometry is a powerful tool for the identification of white dwarfs, there still remains a chance for not recognizing some subdwarfs or binary stars. For a decisive classification, spectroscopy is necessary. Five of our photometrically identified white dwarfs have already been spectroscopically classified, mainly by Greenstein (1980, *Ap. J.* **242,** 738). During two nights in October 1982 we had the chance to take image-tube spectra of 16 others with the Boller & Chivens spectrograph at the ESO 1.52 m telescope. A dispersion of 171 Å/mm was sufficient for these stars with only a few but broad lines.

The spectra alltogether confirm the photometric classification of 14 objects; among the others are a subdwarf, a subdwarf binary and a QSO. If we apply this success ratio of $^2/_3$ to our 46 photometrically identified white dwarfs, there should remain about 30 to be confirmed by means of spectroscopy.

Results, Prospects for Future Research

The most important result of this investigation is the removal of the alleged deficit for cool white dwarfs. This is obtained by application of the just mentioned reduction factor (⅔) to our observed white dwarf numbers and extrapolation of our small observed sky area to the same total area as in Liebert et al. (1979, loc. cit.). We even find slightly more cool white dwarfs than are predicted; this stresses the need for future spectroscopic checks of the photometric identification procedure and for a better statistical basis of our success ratio.

A further result is a substantial increase of the number of observations of southern GD stars. In the sky area under consideration there are about 250 stars brighter than $m_{pg} = 15^m.0$. At the beginning of our project 50 stars had already been observed with 9 stars classified as white dwarfs. We add 78 stars with photometry and 14 with spectra, raising the number of white dwarfs to about 31 (after application of the reduction factor). So Greenstein's (1969, *Ap. J.* **158,** 281) initial experience has been confirmed by the present investigation: GD stars are very promising white dwarf candidates.

In addition to a large number of normal white dwarfs several objects have shown up which are of great interest individually – one extremely hot white dwarf ($T_{eff} \geq 70{,}000$ K, spectral type supposedly DO), one star with a continuous spectrum (DC), a nova-like variable just dropping from its permanent maximum, and an excitingly bright QSO. For these objects extended investigations are planned or already being carried out (e.g. observations with the IUE satellite, October 1983).

It would be worthwile to continue our programme by including objects which are one magnitude fainter to improve statistics for at least one field of the Southern Sky.

Acknowledgements

We would like to thank the ESO staff at La Silla, especially S. Vidal, for their generous and competent help.

High Resolution Stellar Spectrometry: Application to the Li Isotope Problem

J. Andersen, Copenhagen University Observatory, Denmark,
B. Gustafsson, Uppsala University Observatory, Sweden,
D. L. Lambert, Department of Astronomy, University of Texas at Austin, U.S.A.

Background

From the beginning of the ESO 3.6 m telescope project, a high-resolution coudé spectrograph had high priority on the list of auxiliary instruments. Inspired by the results obtained with the high resolution, low-noise spectra from the Tull coudé scanner and Reticon spectrometer at the 2.7 m telescope of McDonald Observatory, the project underwent a metamorphosis from the very classical design foreseen at the start in 1973 to the present highly efficient echelle instrument, the Coudé Echelle Spectrometer (CES). At the same time, the siderostat feed of the early plans was replaced with a real 1.4 m telescope – fondly known as the CAT – of original and very efficient design, thus turning the CES, from a full moon pastime for the 3.6 m, into a full-time powerful facility. Readers of the *Messenger* are already familiar with the instrument from Enard's descriptions (No. 11, p. 22, No. 17, p. 32, and No. 26, p. 22).

A strong argument for this type of spectrometer was the fact that there was – and still is – no other instrument in the southern hemisphere with comparable capabilities. At the same time, several groups in the ESO countries were working actively on problems in stellar atmospheres and stellar and interstellar abundances which required high-resolution spectra of the best possible spectral purity and S/N, such as can be obtained with the electronic detectors of the CES. The expected large demand for observing time on the instrument has not failed to materialize.

With the CES having become a reality, one of us has long wanted to continue his McDonald programmes on some of the many interesting stars that can only be reached from a southern observatory. Another had followed the CES project throughout as a Review Team member and consultant from its inception, and now looked forward to do some real astronomical work of the kinds that were now finally possible. Thus, entering the control room of the CES and CAT to start the first observing run by visiting astronomers on this instrument made us feel much like children on Christmas Eve. That feeling became of course even more vivid when, two nights later, it actually *was* Christmas Eve (1981)! The gifts turned out to be some 25 nights of perfect weather and excellent seeing.

Programmes

One of the purposes of our observing run was to review the performance of the CES on the background of the experience from the McDonald instrument. For this purpose we had chosen a number of different programmes within the field of high resolution spectrometry which were well suited to test the instrument performance, and which at the same time addressed significant astrophysical problems. Among these programmes, we shall mention here those concerning the element lithium. As is well known, Li is a key element in the observational study of stellar evolution, as it is rapidly destroyed in the stellar interior at rather low temperatures. Hence, if convection mixes matter from the surface to sufficiently deep layers, one expects Li to become depleted in the stellar atmosphere, the ^{6}Li isotope more rapidly than the much more abundant ^{7}Li. Consequently, one expects stars to contain less Li the older they are and the more efficient convection and other mixing processes are. Recent extensive work on these problems was done by Duncan (*Astrophysical Journal* **248**, 651, 1981) and Spite (*Astronomy and Astrophysics* **115**, 357, 1982).

However, the agreement of this simplified picture with observations is only very approximate, with several conspicuous discrepancies. Obviously, we also need to understand better by which mechanisms Li can be produced in stars, and to investigate further the connection between atmospheric Li abundance and the degree of mixing of the stellar envelope. Such tests are provided by measurements of the ^{6}Li/^{7}Li isotopic abundance ratio, and of the Li abundance in evolved stars, such as the "weak G-band" stars whose chemical composition suggests that their atmospheres are mixed with large amounts of CNO-processed material from their interiors. But in spite of this evidence for large-scale mixing, some of them show quite strong Li lines, a puzzling behaviour. Our observations nearly doubled the number of "weak G-band" stars with Li observations, and thus considerably enlarged the observational basis for attempts to understand the conditions under which these stars may preserve or produce their Li during their evolution.

We hope to return with a report on these observations before long; in the following, we shall describe our results on the Li isotope ratio.

The ^{6}Li/^{7}Li Isotopic Abundance Ratio

The ratio between the two Li isotopes plays a crucial role in answering the question whether Li may be produced as well as destroyed in stars. Primordial matter should contain a negligible fraction of ^{6}Li (see Wallerstein and Conti, 1969, *Annual Review of Astronomy and Astrophysics* **7**, 99), and the terrestrial and meteoritic ratio is about ^{6}Li/^{7}Li = 0.08. However, the most likely of the proposed processes which could possibly produce Li in main-sequence and subgiant stars, primarily spallation of CNO nuclei by collisions with energetic protons in the envelope, would produce ^{6}Li/^{7}Li ratios of the order 0.4–0.5. Hence, if a star has a ^{6}Li/^{7}Li significantly greater than the cosmic value, this is evidence that Li has been freshly produced in that star, with obvious consequences for the interpretation of Li strengths in terms of stellar age and convection progresses. In fact, Herbig (*Astrophysical Journal* **140,** 702, 1964) and later both Conti (*Ap. J.* **155,** L 167, 1969) and Feast (*Monthly Notices* **134**, 321, 1966; *MN* **148,** 489, 1970) interpreted their measurements of the effective wavelength of the blended Li I feature at 670 Å to indicate that at least *some* stars have ^{6}Li/^{7}Li as high as 0.4–0.5, and Feast speculated that perhaps stars could synthesize Li during their subgiant evolution.

The lithium isotope ratio may be deduced from wavelength measurements as follows: The Li I resonance line is a close doublet. For ^{7}Li, the two components have wavelengths 6707.761 Å and 6707.912 Å, while for ^{6}Li the wavelengths are 6707.921 Å and 6708.072 Å. For each isotope, the ratio between the strengths of the components is 2 : 1, the weaker ^{7}Li component nearly coinciding with the stronger ^{6}Li component. When changing the composition from pure ^{7}Li to pure ^{6}Li, the centre-of-gravity wavelength $\lambda_{1/2}$ of the blend changes from 6707.811 Å to 6707.971 Å. Thus, the ^{6}Li/^{7}Li ratio may be

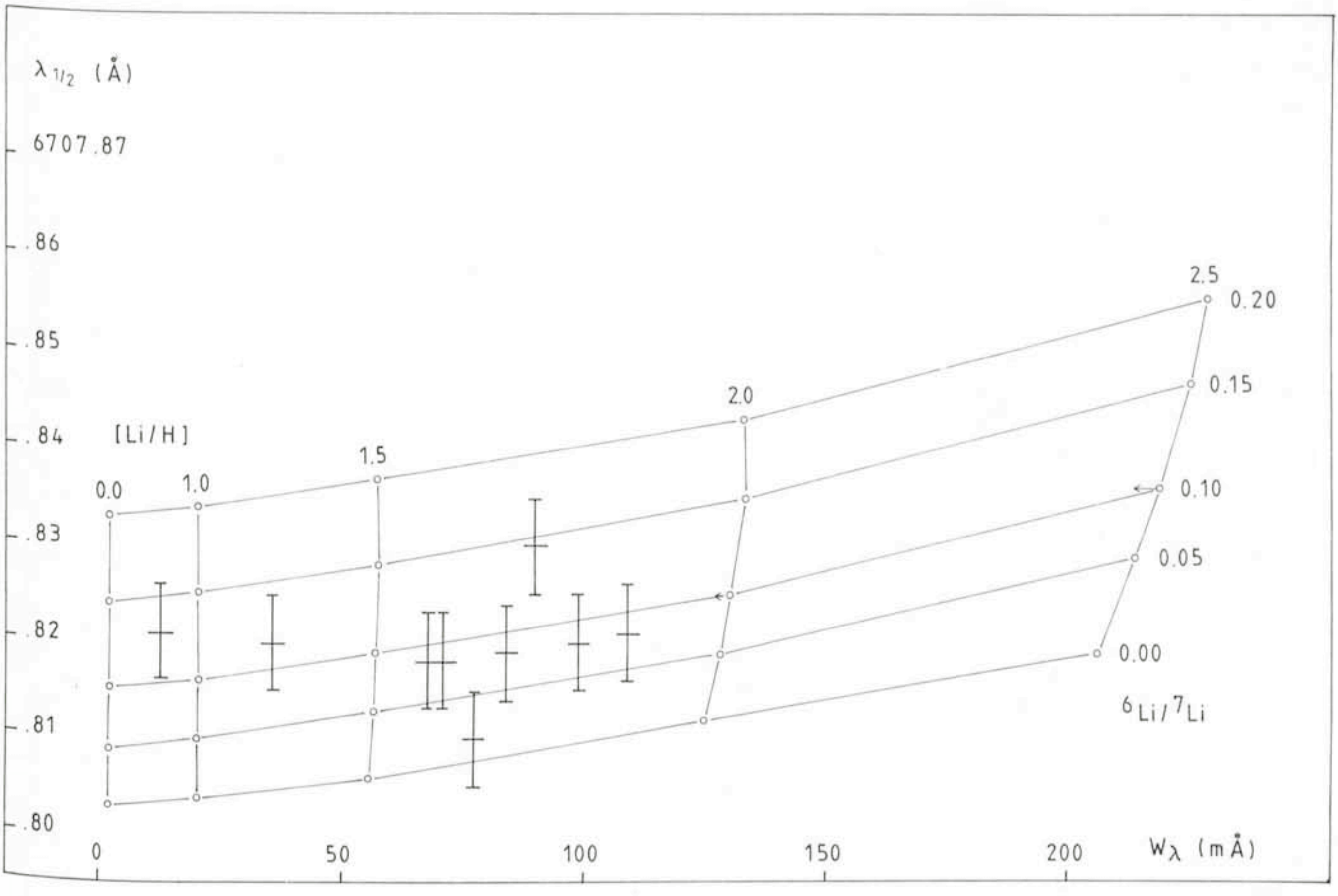


Fig. 1: *Plot of the centre-of-gravity wavelength $\lambda_{1/2}$ of the lithium resonance line vs. total line strength. The grid (fine lines) shows the result of theoretical computations for various Li abundances and isotope ratios while the crosses (heavy lines) show the observed values. The latter have been corrected by –0.005 Å for the combined effects of gravitational redshift and convective blueshift on the solar wavelengths of the (mostly Fe I) stellar lines used to establish the wavelength scale. The small arrows show the effect of decreasing the microturbulence parameter from 2 to 1 km s^{-1} in the models.*

computed from an accurately measured centre-of-gravity wavelength of the Li I line. Measurements on high-dispersion coudé spectrograms were the basis of the results by Herbig and others referred to above.

However, by obtaining high-resolution photoelectric spectral scans and analysing the detailed line profiles, Cohen (*Ap. J.* **171,** 71, 1972) showed that in none of the northern stars considered by Herbig to have high ^{6}Li/^{7}Li was the ratio in reality significantly larger than zero (0.0–0.1±0.1). With the purpose of extending this check to the southern stars with reported high ^{6}Li/^{7}Li ratios, we have obtained high-resolution, low-noise CES Reticon spectra (R = 100,000, S/N > 100) of nine southern main-sequence and subgiant stars in which Li is less depleted from the cosmic value than in the Sun. In the analysis, we have used both $\lambda_{1/2}$ values and detailed line profiles from the CES spectra, compared with synthetic spectrum calculations.

First, we have calculated $\lambda_{1/2}$ for a variety of Li abundances and ^{6}Li/^{7}Li ratios for a range of atmospheric parameters corresponding to our programme stars. As Fig. 1 shows, $\lambda_{1/2}$ does in fact depend both on isotope ratio *and* line strength: For weak lines, we essentially confirm the Herbig relation, but for stronger lines $\lambda_{1/2}$ shifts towards the red due to saturation of the stronger components of the line. The observed $\lambda_{1/2}$ values are also shown in Fig. 1, and it is clear that they are all consistent, with some scatter, with a single value of ^{6}Li/^{7}Li of about 0.10, close to the terrestrial and meteoretic value. There are clearly no cases of the high values indicated by the older photographic observations, but it is interesting to note that also the value ^{6}Li/^{7}Li = 0.00 seems excluded for most of our stars. This is astonishing and interesting, since the present interstellar ^{6}Li/^{7}Li ratio is claimed to be significantly lower than 0.10 (Ferlet, *The Messenger* No. 30, p. 9), and the slow mixing processes suggested to deplete Li in main-sequence stars would also lower the isotope ratio.

We are currently working to refine these results by direct comparison of the observations with detailed synthetic line profiles. Fig. 2 shows the comparison for one of our stars, β Hyi. This figure demonstrates the kind of results that can be achieved with really high quality spectra: The isotope ratio can be determined rather accurately from the line profile itself.

It still remains to carry out similar observations on the last few cases of reported high ^{6}Li/^{7}Li values, e.g. υ And. However, all previous detections having now been disproved whenever subjected to reexamination on high-quality material, one might expect the remaining cases of high ^{6}Li/^{7}Li in dwarfs and subgiants to also disappear under closer scrutiny.

Conclusion

In the *Guidelines to Authors,* the Editor recommends that authors enliven the presentation with amusing stories about the difficulties experienced during the observations. Having had the first visitor run on a new instrument, we must almost apologize for not being able to entertain the reader with dramatic accounts of spectacular breakkdowns, smoking circuits, and floods of tears and liquid nitrogen. We simply sat peacefully night after night at our computer terminals, quietly observing one star after the other, studying already the results

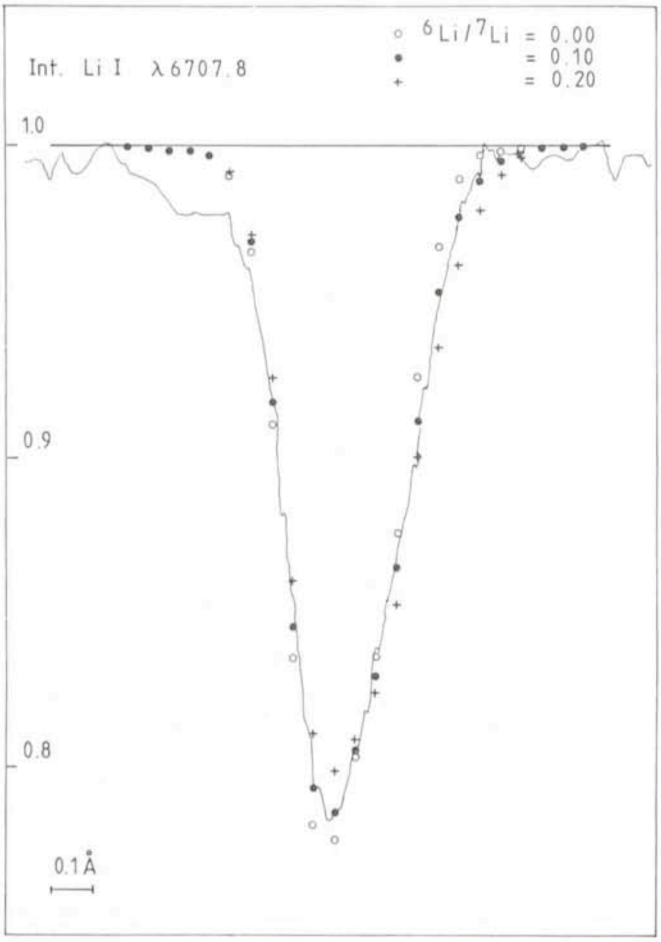


Fig. 2: *The observed spectrum of β Hyi and theoretical Li line profiles (dots) for three isotope ratios. The (VI ?) line at λ 6707.43 in the violet wing of the Li line was not included in the theoretical profiles.*

of the last observation while integrating on the next star, and trying occasionally to remind ourselves what a disgusting place the smelly interior of a darkroom used to be in the old days. On the whole, our run was a very convincing demonstration of the quality and efficiency of this new facility, and Daniel Enard and his colleagues are to be cordially congratulated on this achievement. We trust that our readers will, in the end, share our preference for the kind of excitement derived from new, interesting results rather than from ever so picturesque disasters.

ANNOUNCEMENT OF AN ESO WORKSHOP ON

"THE VIRGO CLUSTER OF GALAXIES"

to be held in GARCHING, September 1984

A large amount of observational and theoretical work has been done on this cluster. The workshop is intended to bring together people with a wide range of experience in an attempt to resolve some of the important controversies such as the membership definition, distance estimates, or the density contrast to the local environment, etc.

Both review papers and short contributions will be given, and there could be two panel discussions (if there is enough interest) on (a) dependence of conclusions on membership assignment to individual galaxies, and (b) differences between Virgo cluster galaxies and "field" galaxies: signs of different evolution or different formation?

For further information, write to:

O.-G. Richter
M. Tarenghi
European Southern Observatory
Karl-Schwarzschild-Straße 2
D-8046 Garching bei München
Federal Republic of Germany

B. Binggelli
Astronomisches Institut
Venusstraße 7
CH-4102 Binningen
Switzerland

Vibrations of Be Stars

D. Baade, ESO

Be Stars – Observed for More than a Century...

Two well-attended IAU symposia in 1975 and 1981 (in the respective proceedings the interested reader may find all relevant references) and an IAU colloquium being planned for the mid-eighties, all three devoted exclusively to Be and shell stars, show that stellar astronomers take a very active interest in these strange objects. The first Be star, γ Cas, was identified as such by Secchi as early as 1866, and today 2–3% of all stars in the Bright Star Catalogue are known to belong to this class. The amount of observational data that has been accumulated is therefore vast, and at all times it has been of the best technical quality. For this reason we are now at a stage where for more and more of these stars it becomes possible (or tempting) to search for periodicities in the (sometimes spectacular) spectroscopic variability exhibited on time scales of years by many Be stars. The idea is that these stars might be binaries and that the mass exchange between the two components is the origin of the line emitting shell around the B-type primary. But for many objects it may well take a few more decades to distinguish with some certainty between true and spurious periods. So far, there is no indication that the binary frequency of Be stars is any higher than the one of "normal" B stars which itself is roughly the same as for O through G type stars.

...and Still Not Understood

In the past couple of years, the discovery of a hot superionized wind with the COPERNICUS and IUE satellites, ground-based polarimetry and extensive model calculations have enormously improved our understanding of the dynamics, structure, dimensions, and thermodynamics of the circumstellar shell. But all this does not help explaining why some B stars, namely the Be stars, possess a shell and the others do not. Up to now, only the binary model can offer an inherent and plausible answer (mass exchange) to this question. But in view of the relatively small number of confirmed binaries, one should not too readily take a possibility for the fact.

Be Stars Do it Faster

The problem with Be stars is, however, even more basic: The fundamental properties of the central stars, like mass, temperature, radius, luminosity, and evolutionary status, are only known with little accuracy. Many Be stars are members of star clusters (e.g. the Pleiades), and so it is well documented that Be stars are lying above and to the right of the zero-age main sequence. But evolutionary effects, a companion, the influence of the shell, and the rapid rotation can *each* account for most of this observation. Even a relative calibration is therefore difficult. The only well-established fact is that classical Be stars rotate faster than "normal" B stars (but it is no longer believed that Be stars are rotating at the break-up velocity and only for that reason losing mass to their envelope). The angular momentum transfer in an interacting binary can spin up a star, but the present statistics do not support the idea that this holds for all Be stars. Thus, we are still left with the question why the phenomenon of superrotation is so much more abundant among B-type stars than within any other class of stars (while binaries are about equally frequent over a wide range of spectral types).

Drilling Holes into Stars

If one wants to look for an explanation, it is probably inevitable to investigate the internal structure of Be stars and to compare it to "normal" B stars. The only means to observationally probe the interior of a star (a Be star in this particular case) whose surface properties are not too different from better known objects (here: "normal" B stars) but ill defined in the individual case, are stellar oscillations. (A very prominent example is the sun whose recently discovered oscillations will probably disclose much about its internal mass and angular momentum distribution.) In the case of the Be stars, oscillations might additionally be involved in the mass loss mechanism. And they permit an interesting speculation: Recent investigations show that rotation and nonradial oscillations can interact with one another so that rotational energy is converted into pulsational energy and vice versa. Should oscillations even be able to explain the rapid rotation of Be stars (which would then only be a surface phenomenon)? – So far, so good. But who said that Be stars are pulsating?

Nonradial Euphoria – Somewhat Damped

The first observations that were interpreted this way were published in the 1979 December issue of the *Messenger*. On photographic spectrograms obtained with the coudé spectrograph of the ESO 1.5 m telescope it had been found that in the Be star 28 CMa all (stellar) absorption lines (except for the hydrogen lines) were asymmetric and variable with a period of 1.37 day. At that time, this was by far the shortest stable spectroscopic period of a classical Be star. By eliminating all other models rather than by strong positive arguments it was concluded that this star is a nonradial pulsator. The crux of this model is that it can explain the unusual lenght of the period (the period of the fundamental radial mode would be just a few hours) the easiest if the pulsation waves are travelling in the direction opposite to the rotation. Theorists, however, had independently found that these so-called retrograde modes are much less likely excited than prograde modes.

Alpha Clavis?

Because of their extreme rotationally caused shallowness, the study of absorption lines in Be stars is quite difficult.The situation is actually even worse since almost all reasonably strong lines are due to hydrogen or helium which, owing to the Stark effect, are mostly useless for the investigation of locally confined velocity variations on the stellar surface (the example of 28 CMa and Fig. 1 illustrate this clearly). But with ESO's new Coudé Echelle Spectrometer (CES) it became eventually possible to discover more Be stars of the same type as 28 CMa. The new data confirmed most of the previous argumentation, the proof of the nonradial pulsation model was nevertheless still pending. Only during my latest observing run at La Silla last June, I had the luck to discover what may be the key star to this problem and, if correct, to some others, too (see above).

Eureka

Fig. 1 shows two sets of four and five profiles, respectively, of the lines He I λ 4471 and Mg II λ 4481 in μ Centauri. The variability of the magnesium line belongs to the most complex ones ever observed in stars. We can see that each profile contains a number (three to four on average) of absorption features. With time, they move from positive to negative velocities across the entire line profile. In addition, the over-all shape of the profile is of variable asymmetry (note that in the helium line only this variation is clearly visible) which evolves the same way. Either variation shows that something is moving on the stellar surface *opposite* to the direction of motion of the rotation! Analysis of a larger number of observations shows that this "something" repeats periodically every 0.101 day for the small absorption features and every 0.505 day for the asymmetry. The period ratio is thus five and means that both patterns are moving with the same angular velocity on the stellar surface because the small absorption components are five times as many as the "asymmetry features".

A Star Like a 20-Bit Orange?

In order to test the nonradial pulsation hypothesis, I have developed a computer programme to calculate model line profiles of a nonradially pulsating star. I could reproduce the

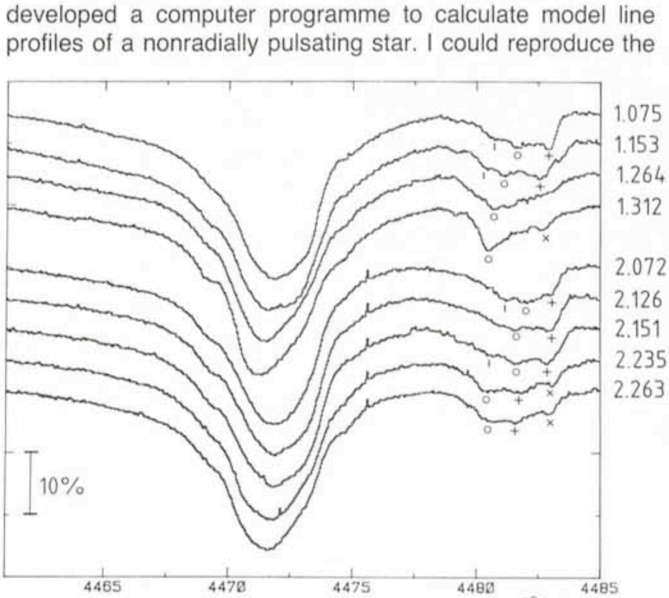


Fig. 1: *Series of 4 (top) and 5 (below) CES spectra of He I λ 4471 and Mg II λ 4481 in μ Centauri, observed with the CAT in two consecutive nights in June 1983. Note the difference between the two lines: The magnesium line is of variable asymmetry with several secondary absorption features superimposed; in the helium line the latter are almost undetectable. The time of the observations (in days, arbitrary zero point) is given on the right. In either group of spectra the secondary components of the magnesium line are identified with different symbols.*

observations of Fig. 1 quite well if and only if a (10, +10) plus a (2, +2) mode were assumed. The meaning of the notation is the following: The first number denotes the number of waves travelling around the star. The equality of the two numbers says that each wave occupies one sector extending from one pole to the other while the azimuthal width of the sector is determined by the number of the travelling waves. (A velocity map of the star would look like an orange whose peeling has been cut into pieces along an according number of great circles.) Finally, the plus sign means that the waves are travelling opposite to the direction of the rotation. In this model, the (10, +10) mode is responsible for the small absorption features in each line while the (2, +2) mode produces the variable asymmetry.

Retrograde in Resonance: A Step Forward

The common angular velocity of the two pulsation velocity patterns strongly suggests a resonant coupling of the two modes. The mutual stabilization could perhaps explain why against theoretical predictions retrograde modes are excited. Independent of the direction of the travelling waves, the ratio of their number in the two modes should be 5 if only surface conditions for the coupling are considered (it remains to be investigated if this means that the observed oscillations are mainly a surface phenomenon). This is indeed found in μ Centauri. Some simple considerations furthermore show that the postulated resonant coupling is much more likely in rapidly rotating stars. This is a nice result since Be stars are the fastest rotators on the right of the zero-age main sequence in the H-R diagram.

Simulations with the above-mentioned computer programme demonstrate that (not surprisingly) the multiple components caused by high-order modes cannot be observed in spectral lines of stars with low v sin i (like 28 CMa) because the intrinsic width of each component is too large to be resolvable. In the past, my observations focused on "slow" rotators because the asymmetry variations due to low-order pulsations which I had been looking for are most pronounced in stars with low v sin i. This (and perhaps also the better performance of the new Reticon array by which the previous one was replaced at the beginning of my last observing run) explains why I missed the unexpected high-order pulsation modes in earlier observations.

Loss of Harmony and Mass

It is tempting, but presently not justified to speculate that all Be stars are pulsating. However, my own observations of a few other Be stars clearly show that the phenomenon is not infrequent in early spectral subclasses (because I was searching for objects related to β Cephei and 53 Persei stars I did not observe later types). This is in line with observations by a group at the University of British Columbia in Vancouver of other early-type Be stars which could be the prograde counterparts to μ Cen (as may be some of the other stars, too, that I observed). This may justify the question if there is a relation between the episodal mass loss of Be stars and their pulsation: Suppose that the coupling of the modes is relatively weak (surface phenomenon?); could it then be that the mass loss is strongly enhanced (shell ejection) when the two pulsations get (temporarily) out of phase?

Bugs in a Pink Sky?

The *Messenger* is a forum where observers may occasionally paint the sky in pink. I should therefore stress that the model for μ Centauri still needs to be tested more extensively. However, if it should pass these tests successfully, the shells of Be stars will become a bit more transparent.

Barium Stars Observed with the Coudé Echelle Spectrometer

H. Holweger, Institut für Theoretische Physik und Sternwarte, Universität Kiel

Barium Stars: Nuclear Accidents that Should Not Have Occurred

Synthesis of heavy elements – by neutron irradiation of iron group seed nuclei – is generally believed to take place during advanced evolutionary stages of red giants and supergiants. Standard theory of stellar evolution suggests that thermal pulses occurring in the helium shell of stars with two active shells provide the mixing and thermal processing required to supply the neutrons. Stars in this stage of evolution are expected to be luminous cool giants and supergiants, with effective temperatures well below 3,500 K and luminosities of $10^3 - 10^4$ $L_\odot$ and more. Indeed, some of the stars which are found in this part of the H-R diagram – the peculiar giants of type S, including the technetium stars – show freshly synthesized heavy elements mixed to their surface.

In contrast, there is another group of red giants – the barium stars – which also show enhanced heavy elements, but who have too low luminosities ($\approx$ 100 $L_\odot$ and less) and too high effective temperatures (4,600 – 5,200 K) to be in the shell flash stage (Scalo 1976, *Astrophysical Journal* **206,** 474). Most probably these stars are less evolved red giants in the helium core burning phase. The elements H, He, and C required to provide the free neutrons are indeed available in such stars, but they occur in different zones well separated by convectively stable layers. Standard evolutionary theory does not predict extensive mixing earlier than in the double-shell phase.

Virtually all Ba stars have low-mass companions (McClure, 1983, *Astrophysical Journal* **268,** 384). Although separations appear too large for any close interaction to have occurred, their binary nature must be related somehow to the abundance peculiarities.

Barium stars are not exotic objects, but make up at least 1 % of all red giants. Our theoretical knowledge of red giant evolution will be incomplete unless we understand why, and how, unorthodox mixing events and release of neutrons can occur in the lower red giant branch. We may hope to learn more about this by studying, in a reasonable sample of stars, the detailed record of this neutron irradiation as provided by the abundance pattern of the various heavy elements.

Analysis of Barium Stars Based on CES/Reticon Spectra

On the observational side, a prerequisite for reliable abundances will be spectra of sufficiently high resolution to yield true

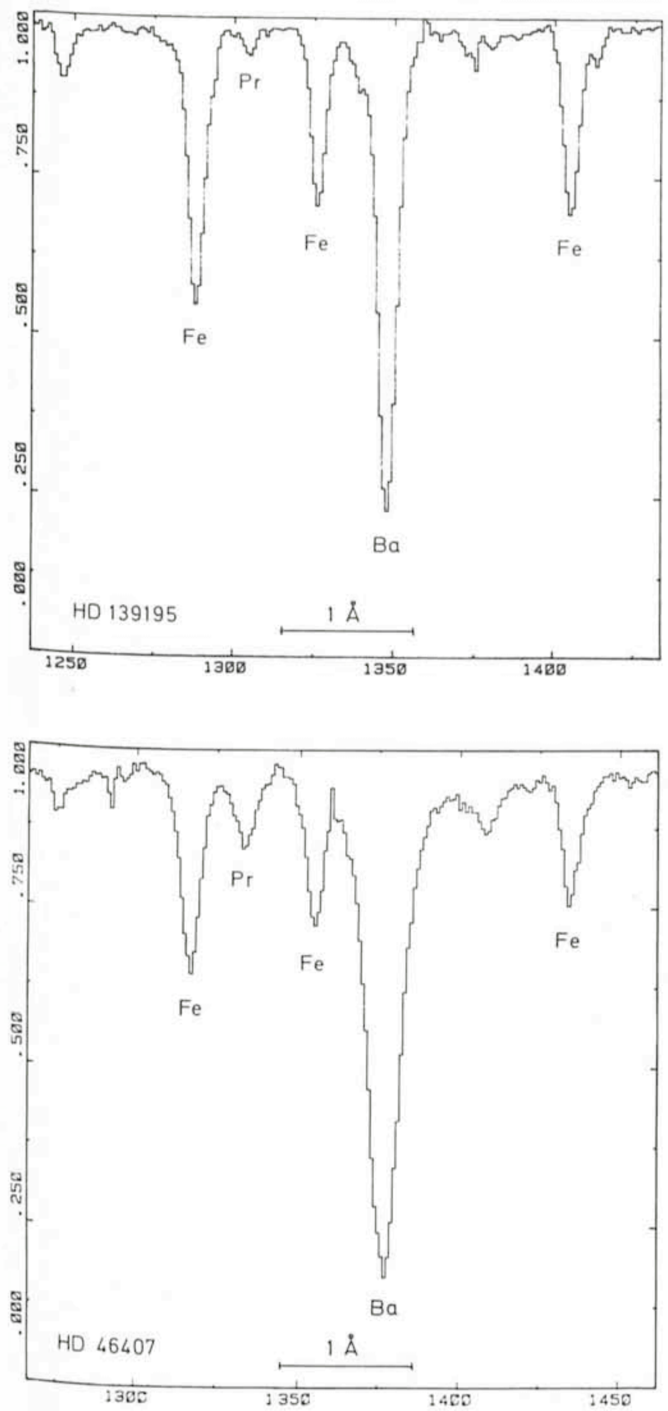


Fig. 1: *CES/reticon spectra of two barium stars, HD 139195 (m_v = 5.3) and HD 46407 (m_v = 6.2). A small section of the original spectrum is shown, extending from channel number 1240 to 1430. The spectrum is centred at the Ba^+ line 5853.69 Å and includes three iron lines and one due to the rare earth element praseodymium. In HD 139195 the Ba/Fe ratio is enhanced with respect to the solar value by a factor of three. HD 46407 is a more extreme Ba star: whereas the iron lines are of similar strength as in HD 139195, those of Ba and Pr are clearly enhanced.*

stellar line profiles. This is particularly important for red giants, where we want to take advantage of their enormously rich line spectrum. A resolving power of at least 10^5 is required; the ESO Coudé Echelle Spectrometer is ideally suited for this purpose.

Another crucial point is the linearity of the intensity scale. The reticon – although a linear detector – has a dark current whose contribution to the stellar signal may become sensible in long integrations at low light level. During my observing period in February 1983 the dark counts accumulated in 90 minutes corresponded to 1 % of the saturation level of the reticon. If your integrated stellar signal is only 5 %, say, of this level, you will have to be pretty sure about how many dark counts you subtract (the dark current was said to be unusually high at that time, and I found it was not sufficiently constant to permit scaling to very different exposures). Thus, if one wants to fully exploit the high photometric accuracy the reticon is capable of, one has to spend quite some time on dark integrations. Nevertheless, the CES/reticon system is very efficient and versatile, and it makes much fun to work with it.

High-quality spectra call for adequate analytical techniques. Most of the earlier analyses of Ba stars employed curve-of-growth methods. Furthermore, most oscillator strengths available at that time are now known to be highly unreliable. In view of this, and of the lower resolution necessitated by photographic spectroscopy, one is not surprised that grossly discrepant results have been reported for the same objects: heavy-element abundances sometimes differing by more than a factor of ten! Model-atmosphere techniques are indispensable, combined with use of solar f-values, and careful consideration of the departures from LTE recently found in red giants.

To my knowledge, heavy-element abundance determinations that conform to these standards are available for only two Ba stars: ζ Cap and HR 774 (Smith et al., 1980, *Publ. Astron. Soc. Pacific* **92,** 809; Tomkin and Lambert 1983, *Astrophysical Journal,* in press). With the ESO Coudé Echelle Spectrometer coming into operation in 1982, a European contribution to this field of research has become possible. In two periods of observation I have recorded reticon spectra of seven southern Ba stars with visual magnitudes ranging from 5.1 to 7.0. Spectral resolution was 100,000 throughout. Two examples are shown in Fig. 1.

One major disadvantage of the CES/reticon system – as opposed to photographic spectroscopy – seemed to me that only a small part of the spectrum can be recorded in one integration: about 40 to 80 Å, depending on wavelength. But now I am convinced that a detailed stellar analysis is nevertheless possible – and even preferable – on the basis of a moderate number of high-quality narrow-band spectra, provided the wavelength bands are carefully chosen to contain spectrum lines of strategic importance. On average, six wavelength bands were recorded for each star, distributed over the wavelength range 5180 to 10330 Å. Integration times were typically 80 min. for the Ba star HD 46407 (visual magnitude 6.24); somewhat larger exposures were needed in the near infrared, and the Sr^+ line at 10327 Å could be reached only in the brighter objects of my sample.

Model-atmosphere analysis of these spectra is currently carried out at Kiel. Dr. N. Kovács, who is engaged in this project, has already published results for two of the seven Ba stars, HD 65699 and HD 83548 (*Astronomy and Astrophysics* **124,** 63).

Selective Enrichment of Magic Nuclei

Six of the seven Ba stars of our sample show the typical enrichment pattern which other investigators have found among other objects of this type: overabundances relative to iron of all spectroscopically observable heavy elements that can be synthesized by slow neutron capture, e.g. Sr,Y, Zr, Ba and the rare earth elements La, Ce and Nd. Minor differences from star to star may be attributed to slightly different neutron irradiation which, in any case, must have been quite strong in order to convert iron "seed" nuclei into those heavy elements. The overall heavy-element content of these "ordinary" Ba stars requires only a small fraction of the stellar envelope to have

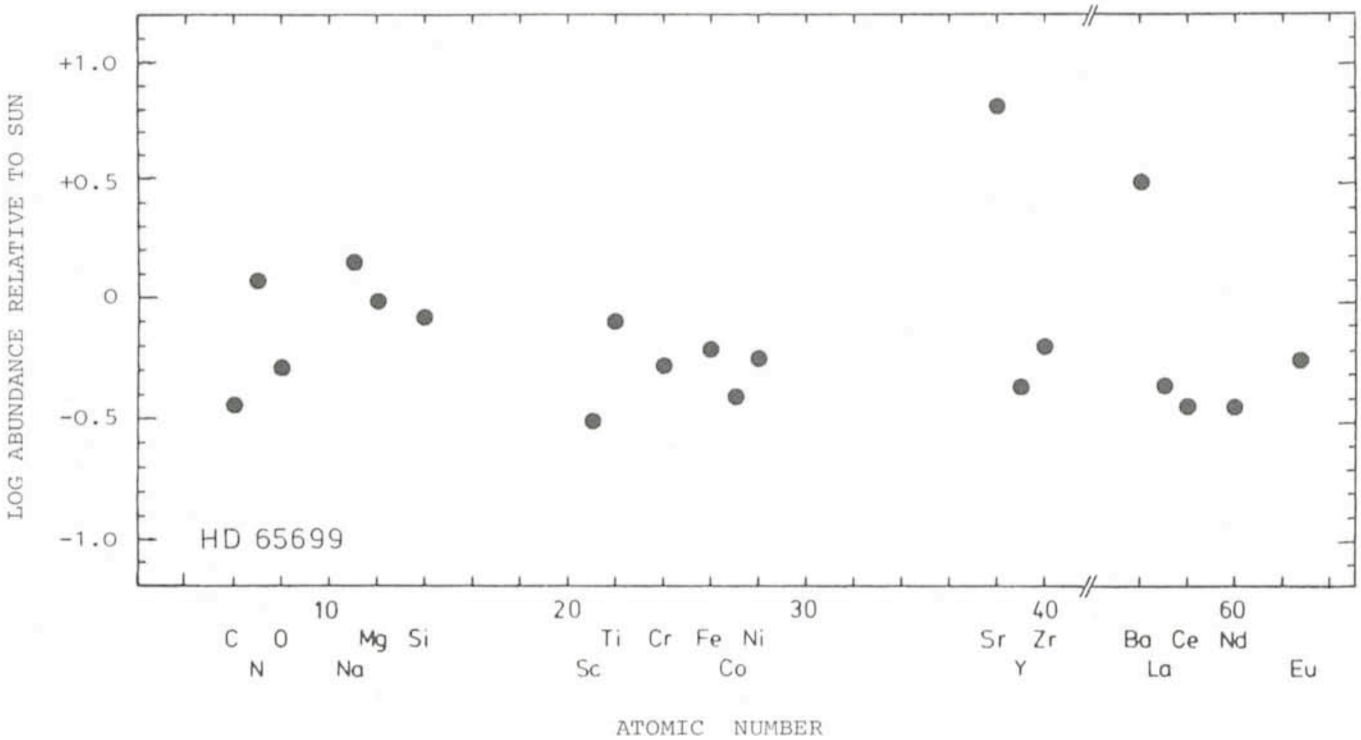


Fig. 2: *Elemental composition of the Ba star HD 65699 showing selective enhancement of strontium and barium (Kovács 1983).*

been processed. In the case of HR 774 quoted above, this fraction is of the order of 0.1 %.

In contrast, one of the Ba stars – HD 65699 – exhibits a peculiar abundance pattern. Barium is enhanced by about a factor of four, and strontium even more, but the other observable heavy elements are virtually unchanged (Fig. 2). Interestingly, there seems to be a connection to normal giants. In recent years five bright red giants and a supergiant – all of spectral type K – have been analysed at Kiel on the basis of high-dispersion photographic spectra, including 3.3 Å/mm plates taken at the ESO 1.5 m telescope. According to Kovács (1983, *Astronomy and Astrophysics* **120,** 21), two of these evolved objects – α TrA (K4 III) and ε Peg (K2 Ib) – show a selective enrichment of Ba (the Sr abundance is not yet known). It seems to me that the high-quality CES/Reticon data of the Ba star confirm that a chemical peculiarity of this kind may occur among evolved objects.

The question arises which sort of slow neutron capture process is able to selectively enrich Sr and Ba. A clue to this puzzle may be found in the systematics of neutron capture cross-sections of the heavy nuclei involved. By far the smallest cross-sections occur at the "magic" nuclei ^{88}Sr, ^{138}Ba, and ^{208}Ba, possessing closed neutron shells with 50, 82, and 126 neutrons, respectively. Small cross-section means that the nucleus has only a small chance to capture a neutron, and thereby to increase its mass by one unit as required in order to proceed towards heavier elements. The traditional scheme assumes that there are so many free neutrons available that these barriers are easily overcome. A large range in mass is produced; the resulting abundance pattern depends on the individual cross-sections and on the details of the irradiation event(s). This process obviously has operated in the "ordinary" Ba stars, and is responsible for their general enrichment of heavy elements. However, there seems to be no way to produce only Sr and Ba, and leave elements like Y, Zr, La, Ce, and Nd unchanged.

A simple variant of the traditional scheme appears more promising. In a forthcoming paper together with N. Kovács we report calculations – employing recent neutron capture cross-sections – which show that selective enhancement of Ba can indeed be obtained if the neutron irradiation is weak, shifting pre-existing heavy nuclei of normal population I matter by only a few mass units. This mild irradiation piles up excess abundances at the magic nuclei, at the expense of the elements immediately preceding Ba. Among those, Sb, Te and Xe are predicted to show the largest depletion; unfortunately we cannot check this observationally because these elements are not accessible to spectroscopy. But Ba and some of the rare earth elements following Ba are accessible. Our model predicts

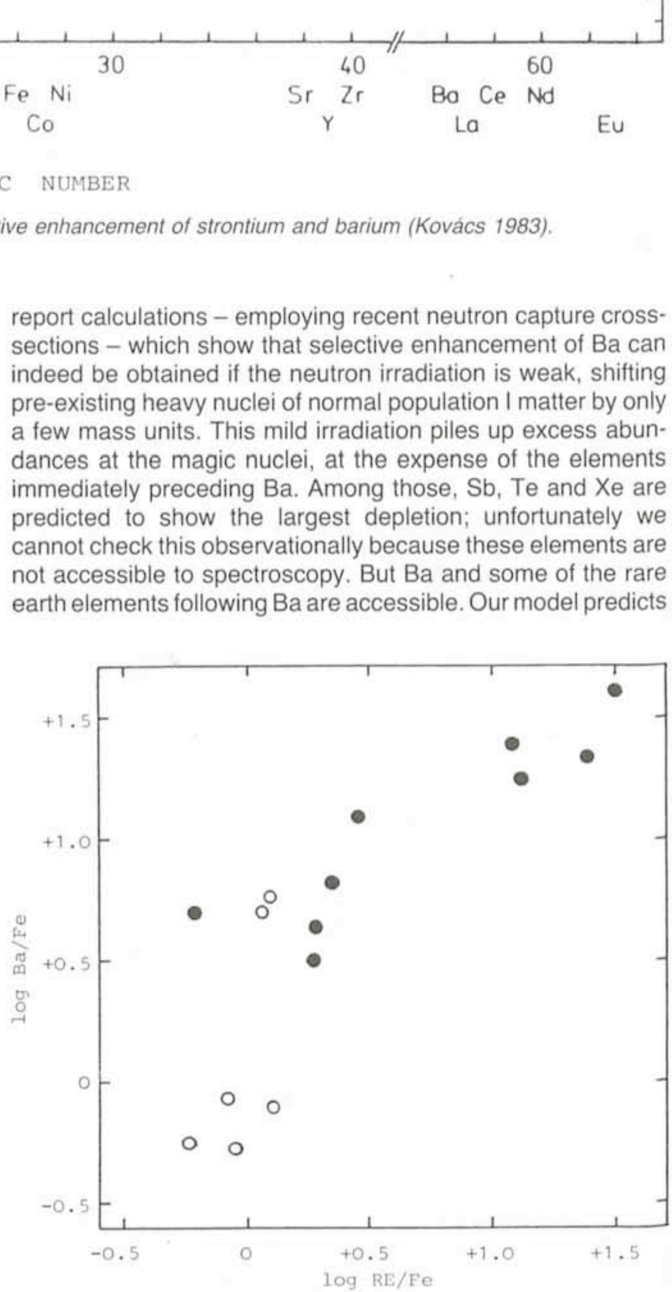


Fig. 3: *Enhancement of barium versus enhancement of rare earth elements (La, Ce, Nd) in Ba stars (filled circles) and "normal" red giants (open circles).*

an increase of the barium abundance by a factor of three, whereas La and Ca change by less than 15% – in agreement with what we find in HD 65699, α TrA, and ε Peg.

The distinguishing feature of this alternative scheme is that it involves weak processing, yet of a large fraction of the stellar envelope. HD 65699, α TrA, and ε Peg appear to be extreme cases. The data so far obtained from high-resolution spectroscopy of K-type giants and Ba stars are collected in Fig. 3, which also includes the analyses of ζ Cap and HD 774 by Smith et al., and by Tomkin and Lambert cited above. Fig. 3 suggests that a whole sequence of combinations of neutron irradiation and mixing exists – while standard theory of stellar evolution does not predict any production of heavy elements at the relatively high effective temperatures and low luminosities of our objects!

The Optical Pulsar H 2252-035 (AO Psc)

M. Kubiak, Warsaw University Observatory, Poland, and Hoher List Observatorium, FRG

The optical counterpart of the pulsating X-ray source H 2252-035 appeared to be an interesting object for optical astronomers also. In the X-ray domain it shows the same characteristics as other pulsars. Its X-ray emission is modulated with a period of about 805 s, the pulse amplitude being about 25% in the energy range 5–15 keV, 50% in the range 2–5 keV and almost 100% between 0.1 and 4 keV. The increase of pulse amplitude with decreasing energy is the only feature distinguishing this object from the other neutron star pulsars.

For the optical astronomers the source looks like a typical cataclysmic variable, most probably consisting of a compact object (magnetic white dwarf or neutron star) and a low mass star orbiting with a period of about 3.6 h, revealed by both photometric and spectroscopic observations. What makes, however, the object particularly interesting is the presence of additional light modulations with periods of about 805 and 859 s. The first period corresponds exactly to the period of X-ray flux modulation; the second one, however, is not independent from the two others: the difference of frequencies corresponding to the 805 and 859 s periods is equal to the frequency of the orbital motion. As all three periods are real and can be observed as independent light modulations, this means that the 859 s period is connected with radiation emitted originally with an 805 s period and "reflected" somehow from an element of the system taking part in (prograde) orbital motion.

Thus, we can adopt the following working model of the system (J. Patterson and Ch. Price, 1981 *Astrophysical Journal,* Letters, **243,** L83): A close binary contains a compact object – the pulsar – fed by the matter being lost by a dwarf secondary and accreted via a disk by the magnetized compact primary. A moderately strong magnetic field of the primary channels the accretion at the polar regions, giving rise to intense X-ray and optical radiation emitted mainly within a cone the aperture of which depends on the details of the emission mechanism. Rotation of the compact star modulates the X-ray and optical emission with the period of 805 s. A part of the X-ray flux is reprocessed – in the secondary's atmosphere or somewhere in the accretion disk – and observed by an external observer as the 859 s modulation in the X-ray emission.

In order to enlarge somewhat our knowledge of the optical characteristics of the system, H 2252-035 was observed on five nights, between 3 and 10 October 1982, with the standard UBV

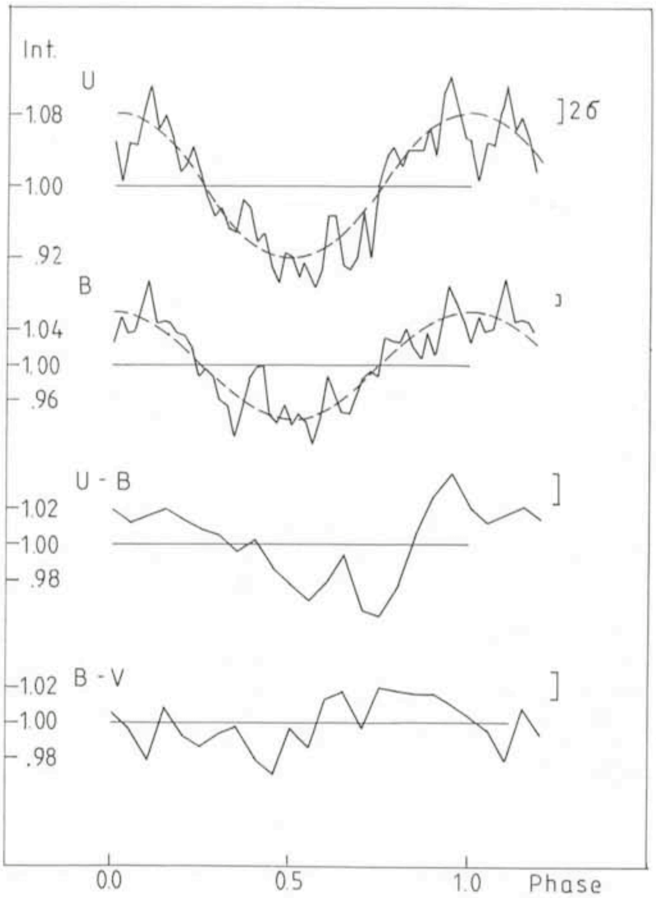


Fig. 1: *Mean brightness and colour changes with orbital period (in intensity scale). Broken curves – sinusoids resulting from periodogram analysis.*

Table 1. Results of periodogram analysis

Periodicity	U amp	U Φ	B amp	B Φ	V amp	V Φ	U – B amp	U – B Φ	B – V amp	B – V Φ
orbital	0.083	– 0.19	0.062	– 0.02	0.047	0.19	0.025	0.36	0.016	– 1.19
reprocessed	0.044	– 1.50	0.036	– 1.62	0.021	– 1.93	0.013	– 1.97	0.008	– 0.98
pulsar rotation	0.025	1.29	0.012	1.51	0.013	0.15	0.011	1.38	0.007	2.69

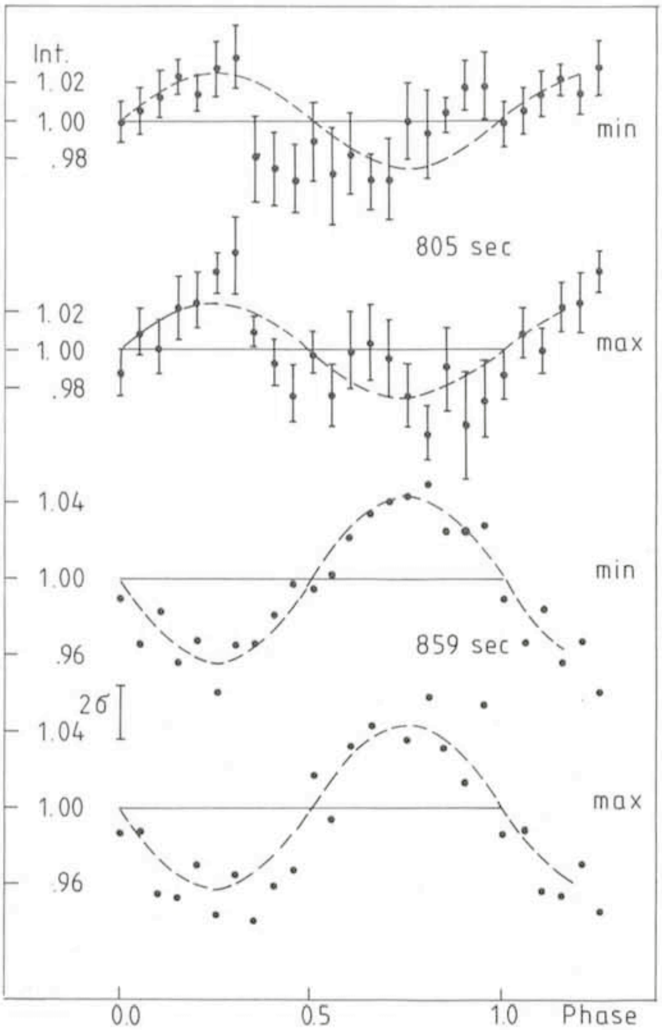


Fig. 2: *Mean light-curve of both short period modulations at minimum and maximum light of the orbital period, respectively.*

photometer attached to the 1 m photometric telescope on La Silla. Integration time was 5 seconds in each pass-band. A nearby 13-magnitude star was used as comparison. Altogether 1,333 integrations in U and V, and 2,083 integrations in B have been secured. The average magnitude and colours are: V= 13.35 ± 0.03, B – V = 0.01 ± 0.01, U – B = –0.86 ± 0.02.

Table 1 shows the results of the periodogram analysis of the data. Amplitudes are given in intensity units, and are practically the same in magnitude scale. Phases, given in radians, are counted from HJD 2445246.59480. The average 3σ noise, remaining in the periodograms after subtracting the three frequencies, is of the order of 0.002 and characterizes the accuracy of amplitude determination.

The data, after subtracting the short period modulations, were folded with the orbital period, giving the average light and colour curves shown in Fig. 1. Broken curves in this figure represent the sinusoids resulting from the Fourier analysis. The average orbital light-curves seem to be well defined in all pass-bands and their following features are worth to be stressed: (i) if we accept the results of the periodogram analysis (i. e. that the light-curve is a sinusoid best fitted to the observations) then the maximum light occurs between two remarkable peaks of brightness at phases 0.95 and 0.1; (ii) the light-curve contains other permanent features like, e. g., the peak at orbital phase of about 0.4 or the dips near the phases 0.0, 0.5, and 0.7; (iii) colour variations, although more or less sinusoidal, seem to show asymmetry relative to phase 0.5.

The interpretation of the light-curve in this case is not an easy task. In fact, it is even difficult to say if there is an eclipse in the system or if we only see the different aspects of the revolving accretion disk. The presence of secondary minima and maxima in the light-curve (if they are permanent indeed) could be, for example, the result of successive eclipses of hot spots by obscuring matter present in the system (secondary star, clouds in other Lagrangian points?). Somewhat different conclusions result, however, from the slopes of the continuous spectrum. The constant part of the observed flux appears to be flat, decreasing with wavelength as $\lambda^{-1.8\pm.2}$. The modulated part goes down much steeper, approximately as $\lambda^{-3.6}$. This does not completely exclude the possibility of eclipses, but suggests that the main part of the modulated light is produced by a different mechanism than the constant component.

The collected observations give also a possibility to study in more detail the remaining two short period variations. Their amplitudes and phases have already been given above. Phase difference is such that the two sinusoids are always in anti-phase at maximum of the orbital light-curve (and in phase at minimum light). This means that at maximum orbital light the site of reprocessed light is in upper conjunction with the primary source of radiation. Folding of all the data with 805 and 859 s respectively shows that the reprocessed light-curve is very regular and practically sinusoidal in all three pass-bands. The 805 s variations have smaller amplitude and a shape deviating more from a sinusoid. As the averaging over the whole observational period can smooth the picture too much, it may be instructive to look at the behaviour of both variations as a function of orbital phase. Fig. 2 shows the mean light-curves for both periodicities but within ± 0.15 of the orbital period around maximum and minimum light, respectively. Only results for U-

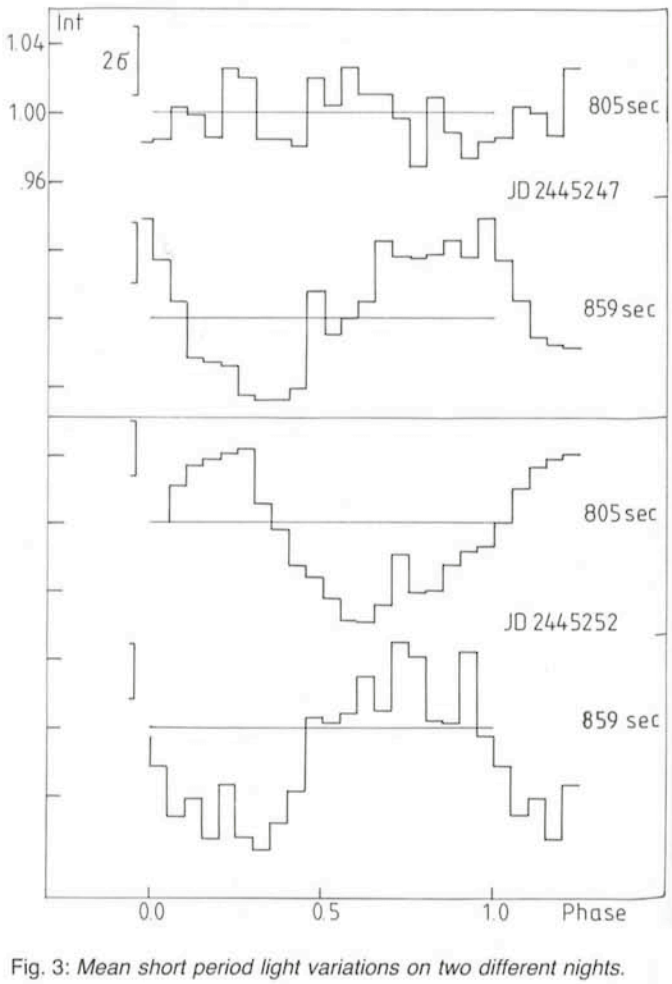


Fig. 3: *Mean short period light variations on two different nights.*

band are given, but essentially the same is observed in B and V.

In spite of a relatively larger scatter, it seems obvious that there is no phase dependence in the reprocessed light and a slight phase dependence in the 805 s modulation. The latter shows also a remarkable cycle to cycle variability. This may be seen from Fig. 3 where the mean short period light-curves are shown for two different nights. The 859 s modulation is practically the same on both nights and essentially not different from the overall mean. On the contrary, the 805 s modulation is almost invisible on one night and very strong on the other.

Apparently the site where the original radiation is being reprocessed is located far enough from the disk so that both illuminating and reprocessed radiations can travel to and from it practically undisturbed. The changes in the 805 s optical light modulation cannot be interpreted unambiguously: they can reflect the changes in its source as well as the changes in the system.

Another feature of H 2252-035 which perhaps is worth mentioning is the stability of the 859 s period (and implicitly the 805 s period also). The present observations combined with previous determinations lead to the following light elements:

$$\text{HJD maximum} = 2445246.60275 + 0.009938388 \cdot E$$

The orbital period can be determined with less accuracy but its new ephemeris,

$$\text{HJD maximum} = 2445246.59480 + 0.14960 \cdot E$$

proves the constancy of the period over more than 5,400 cycles. The fact that the pulsar rotation period changes less than about $7 \cdot 10^{-7}$ cycle per year suggests that the rotating body is a white dwarf rather than a neutron star. The rotation of the pulsar is not bound – during one orbital period the white dwarf makes 16.05 revolutions – and this situation seems to be satisfying for the system.

In this note only fragmentary facts about H 2252–035 are given; the full account of observations is in preparation.

The New Data Acquisition System for ESO Instrumentation

P. Biereichel, B. Gustafsson and G. Raffi, ESO

New instrumental control and acquisition software has been developed for the on-line minicomputers on La Silla. This has been done to allow easy portability of programmes between the various installations, to shorten the development time for new programmes, to ease software maintenance problems, and to provide the observer with a common, high-level interface to the various instruments.

Introduction

Over recent years, problems have often been experienced due not only to the ever increasing number of instruments, detectors, not to mention telescopes installed on La Silla, but also because the detectors and instruments themselves tend to be used in new configurations. The CCD camera, for example, was initially used only for direct imaging on the Danish 1.5 m telescope. Now CCDs are used, in addition, on the 3.6 m telescope for direct imaging (prime focus), with CASPEC (Cassegrain Echelle Spectrograph), with the Boller & Chivens spectrograph, (soon) with EFOSC (ESO Faint Object Spectrograph and Camera), and also with the Boller & Chivens and for direct imaging on the 2.2 m telescope.

Developments such as these can naturally lead to a software implementation and maintenance nightmare as well as making the instrument control often confusing to the observer. It is precisely these sort of problems that the new software package has been designed to cope with. The new software is therefore modular like today's instruments, and these modules, being independent of other parts of the system, are completely portable. The system comprises three main components: general-purpose programmes, libraries of subroutines, and protocols that govern the communications between the different parts. All of these components are detector-, instrument- and telescope-independent. Most of the programmes referred to are new, although a few are older ones that have been adapted to the new software environment.

The "user interface" is implemented by means of a Terminal Handler programme that is used by all instruments and provides a high-level standard interface to the user. This package allows an easy implementation of many desirable features such as the possibility of carrying out automatic sequences of integrations with pre-selected instrumental and telescope parameters.

This article is intended to give a general overview of the system. Full documentation is available from the TPE group, ESO Garching.

System Features

The new instrumentation software runs on Hewlett-Packard HP 1000 minicomputers, under the RTE-4B operating system. Fig. 1 shows a diagram of the standard configuration for an ESO instrumentation computer in the case of a CCD-based instrument. The software components of the data-acquisition system are shown in Fig. 2 and the main features are described below.

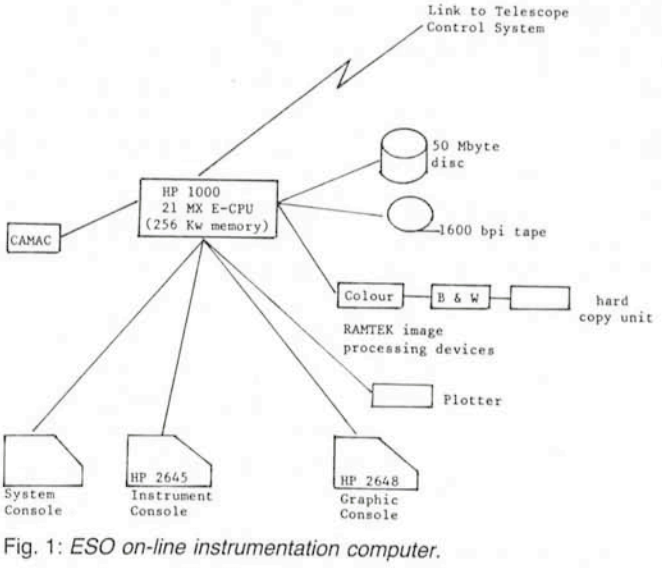


Fig. 1: *ESO on-line instrumentation computer.*

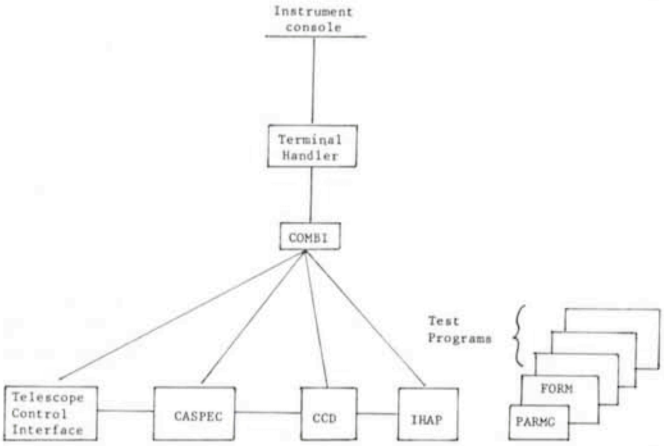


Fig. 2: *Data-acquisition system components.*

– The Terminal Handler programme coordinates and transmits commands and status information between the instrument console and the various programmes involved. User input and output is by means of function keys (softkeys) and tables (forms). The instrument console displays, typically, a softkey menu at the top of the screen, followed by several lines of status and alarm information. The lower part of the screen is

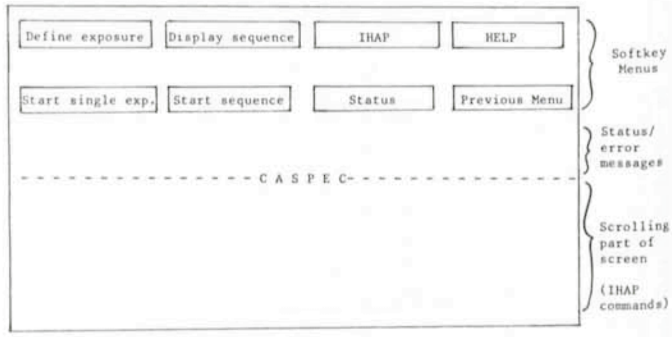


Fig. 3: *An example of instrument control layout (from CASPEC).* Note: *Areas in ▭ boxes have white background (inverse video).*

<---	Exposure	definitions	--->							<- Instr.	setting ->		
#	TP	h.	mm.	ss	MT	Identifier	Batch::	CR	#Exp	Y/N	LS	Slit	Density
1	DK	0.	20.	0	0	DARK 20S	AVERAG	1	2	1	0	90.0	40.0
2	CL	0.	1.	0	0	CALIBR. HEAR 1M	CCDSP$	1	1	1	4	90.0	40.0
3	FF	0.	2.	0	0	INTERN. FF 2M	AVERAG	1	5	1	2	90.0	40.0
4	RE	0.	5.	0	0	NGC4594 5M	CCDSP$	1	1	1	0	90.0	40.0
5	RE	0.	20.	0	0	NGC4594 20M	CCDSP$	1	1	1	0	90.0	40.0
6	RE	0.	20.	0	0	NGC0055 20M	CCDSP$	1	1	1	0	110.0	40.0
7		0.	0.	0	0			0	0	0	0	.0	.0
8		0.	0.	0	0			0	0	0	0	.0	.0

<---	Telescope	setting	--->					
#	Y/N	Ident.	hhmmss.s	Sddmmss.s	yyyy.dd	nnnn.mm	nnnn.mm	A/M
1	0		0 0 0.0	0 0 0.0	.00	.00	.00	
2	0		0 0 0.0	0 0 0.0	.00	.00	.00	
3	0		0 0 0.0	0 0 0.0	.00	.00	.00	
4	1	NGC4594	123910.0	-1131 9.0	1983.00	.00	.00	M
5	1	NCG4594	123910.0	-1131 9.0	1983.00	.00	.00	M
6	1	NGC0055	014 6.0	-3917 0.0	1983.00	.00	.00	M
7	0		0 0 0.0	0 0 0.0	.00	.00	.00	
8	0		0 0 0.0	0 0 0.0	.00	.00	.00	

TP=Exp. type, MT=tape recording, LS=Light source, #Exp=Number of exp.
# =Relative sequence number, Y/N: Setting (Yes=1, No=0)

Fig. 4: *Table for exposure sequence, as it appears when printed (from Boller & Chivens at 2.2 m telescope).*

reserved for a scrolling display of IHAP and other commands (see Fig. 3).

– Control of the various instrument functions is effected by means of CAMAC microprocessor-based motor controllers which were developed at ESO. These are used by the instrumentation software to control either DC or stepper motors with different types of encoders and are interfaced to the control programmes via a library of standard subroutines.

– A generalized version of the parameter manager programme developed for the Coudé Echelle Spectrometer to define instrument parameter tables also forms part of the data-acquisition system.

– The CCD software package has been developed within this framework and is the kernel of all CCD-based instruments. The CCD software controls and monitors the CCD detector via microprocessor-controlled electronics. It executes exposures on instrument request and stores acquired data on disk and tape in either IHAP or FITS format, as required.

– The IHAP data-processing system is used for on-line data reduction. IHAP shares its data-base with the CCD programme so that data are written onto disk only once. It can be used from the instrument console, either via direct commands or soft-keys. The IHAP graphic terminal is used for instrument status displays, when IHAP is not active. The instrument and detector parameters are recorded together with data on disk and tape using a dictionary of FITS keywords.

– Communication among programmes is defined by a number of interfaces: Instrument/Detector, Data-Acquisition System/Telescope-Control System, Data-Acquisition System/IHAP. Messages are passed using a "mailbox".

Giancarlo Setti, Head of the Scientific Division since 1 January 1982. This picture, taken by G. Vettolani on June 29, 1983, during the dinner offered by the Mayor of Medicina (where the radio telescope of the University of Bologna is located) to the participants at the Bologna IAU Symposium on VLBI, shows that G. Setti is still able to enjoy life.

What Do the Users Gain?

Although the system has been developed with the needs of maintenance engineers and designers in mind, the main focus of the development has been the eventual users of the system: the visiting astronomers.

Communication with the instrument, detector, telescope control software, and on-line data reduction are carried out from a single terminal as if they all formed part of one unique comprehensive package, while the complications of the multi-programme design are invisible to the user. Thus, the whole sequence of events needed to set up an observation – setting detector and instrument parameters, pointing the telescope and analysing previously acquired data during integrations – forms an easy to understand and natural process. The use of soft-keys and parameter-tables helps considerably in this respect and users can quickly familiarize themselves with the system without the need to remember dozens of parameters or use manuals. (A "Help" key is provided for every menu level.)

The system also provides ample scope for the advanced user to carry out more sophisticated observing procedures. Complete "observing programmes" can be pre-programmed in advance so that a sequence of integrations with different instrument settings and telescope positions can be executed automatically with the minimum waste of observing time. Multi-exposures at different focus settings is a special sequence that is available for direct imagery. Fig. 4 shows an example of a table to be filled in interactively to execute such an observing programme. This specifies exposures of different types (e.g. calibration, flat-field or star exposures) which can be repeated, sequenced and linked with IHAP batch programmes for immediate data reduction.

The use of a standard terminal without any hardware control panels, and the modular software structure will also allow the implementation of a remote-controlled version of the instrumentation software to be used for remote observing experiments.

The needs of the visiting astronomer might seem to conflict with those of the local engineering staff as the latter need maximum flexibility and must be able to enter individual control functions at a fairly low level. This need is supported by the intrinsic structure of the instrument and detector packages which are internally split in two modules. The "outer" module deals with the instrument logic in terms of tables and softkey management. The "inner" module can be considered as the instrument/detector "software controller". As such it receives and executes more basic commands of the type:

– CLOSE SHUTTER, LAMP 1 ON, DECKER 1230 (i.e. move decker to encoder position 1230).

Communication to these programmes is through what is called the engineering interface, and is implemented in terms of ASCII commands of the type shown above. The possibility to pass commands at this level is maintained when the "outer" software is operational and coexists with the higher level command-entry. Thus engineering commands for tests and maintenance can be entered at any time via the top level programme (the instrument programme as seen by the user), either directly or via test programmes accessible by means of the maintenance softkeys.

Conclusions

The new software system developed for ESO instrumentation supports:

– portability of software among instruments and telescopes
– automatic observing programmes

– easy access to the engineering interface.

Thanks to the modular system structure, duplication of development effort is avoided and the number of programmes to be maintained is minimized. The new software has been developed as a by-product of the on-going instrumentation projects, with the aim of rationalizing the instrument software. While it is believed that this goal has been successfully achieved, some areas could still be further improved. In particular some work will have to be done to make instrumentation software suitable for remote control, even on a relatively low-speed computer-to-computer telephone link.

Acknowledgements

The authors would like to thank F. Middelburg for the additions to IHAP which have allowed easy interface to the new data-acquisition system. The on-line availability of IHAP considerably increases the power of the whole instrumentation software.

A special word of thanks is due to H. Pedersen for his recommendations and for his belief in fully computerized observing programmes, the Danish telescope CCD being the first example of this; and to M. Cullum for his careful reading of the manuscript.

Pulsating Stars, Spectroscopy and Shock Waves

D. Gillet, P. Bouchet and E. Maurice, ESO

The pulsating stars constitute an important group of variable stars. They show in their spectra a large number of variations (intensity, shape, emission) which are very well observed with high-resolution spectrographs equipped with modern receptors. These spectral variations are the consequence of the dynamic state of the pulsating atmosphere of the star and their study can certainly give some fundamental information. Here, in the first section, we give a rapid review of the observations of emission lines and their interpretation by the propagation of a shock wave through the atmosphere of various types of pulsating stars. Later, the Hα emission of Mira Ceti, the brightest Mira star in the sky, is analysed. It is shown that the

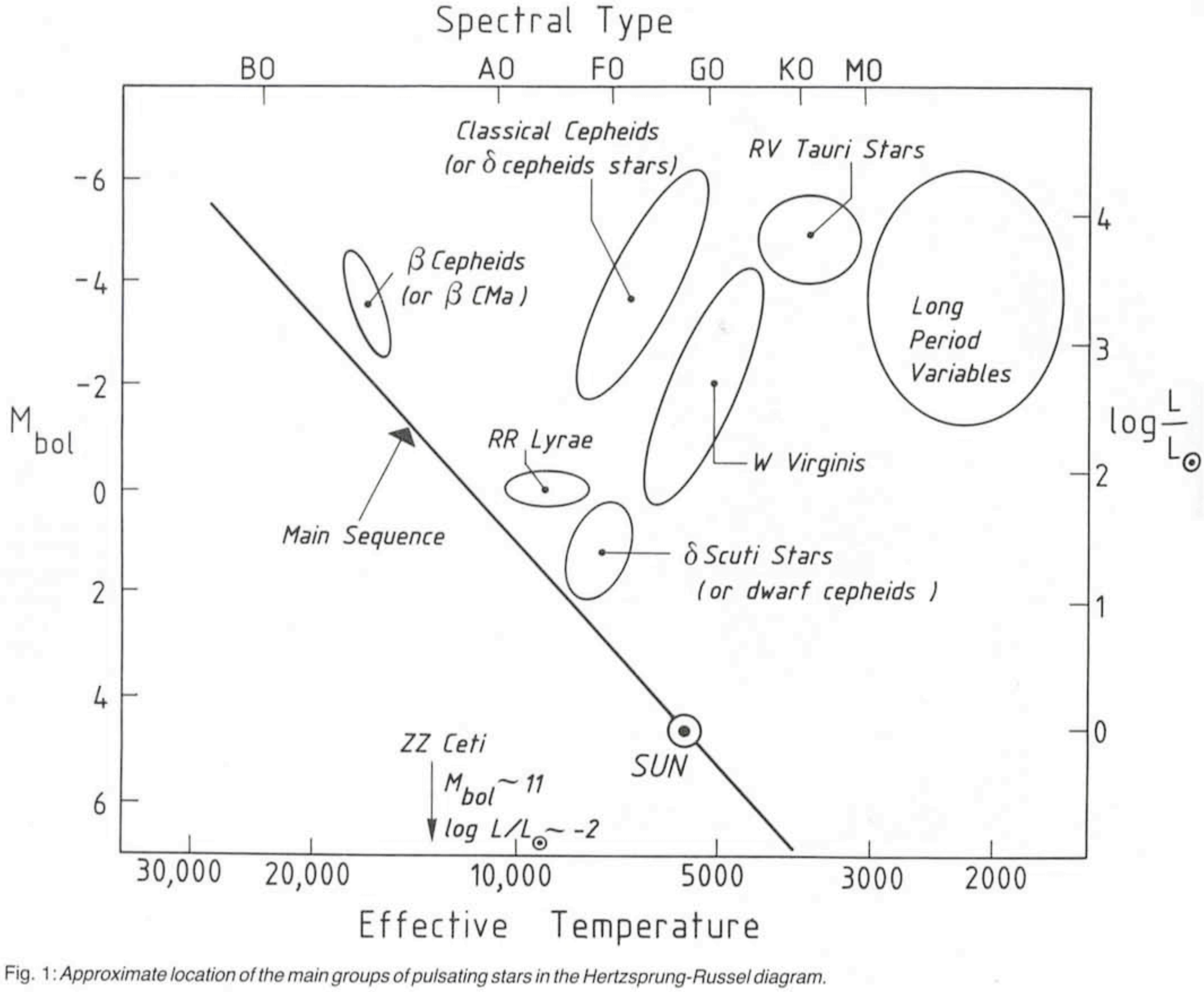


Fig. 1: *Approximate location of the main groups of pulsating stars in the Hertzsprung-Russel diagram.*

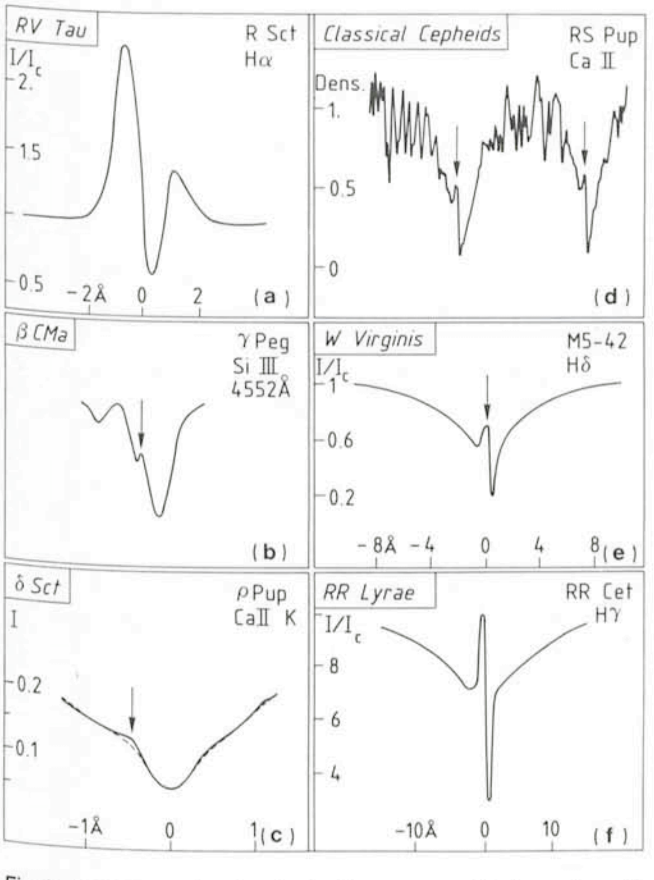


Fig. 2: *A few examples of emission lines supposed to be produced by shock waves propagating through the atmosphere of pulsating stars. All these pictures are adapted from references (a) to (f).*

intensity of the emission profile can be very different in each period.

Pulsating Stars and Shock Waves

Fig. 1 shows the classical Hertzsprung-Russell diagram. The approximate position of different groups of pulsating stars is given. A comprehensive list of their characteristics can be found in Dürbeck and Seitter (1982). Apart from ZZ Ceti stars (variable white dwarfs of short period), the pulsating stars are in majority "above" the main sequence, i.e., in regions where the nuclear activity is relatively rapid. Their luminosity varies with a period between 100 s to 1,000 days and with an amplitude between 0.01 and 8 magnitudes. When the star undergoes, by gravity, a compression, the temperature and the pressure of the atmosphere increase and the hydrogen and, principally, helium, by their ionization, stock potential energy. When the recombinations occur, the radiation pressure increases and exerts pressure on the outer layers of the star. This mechanism (the motor of the pulsation) in which the energy dissipated by the pulsating motion is replenished by the effect of the changing of the opacity due to the ionization, counterbalances the damming process and thus perpetuates the pulsations.

During the pulsating motion, the atmospheric gas undergoes accelerations and decelerations. Thus, it is possible, in principle, that shock waves are created. There are at least two observational features in favour of these waves. The first is the presence of discontinuities within the radial velocity curve and the second, the existence of emission lines. However, these facts are not compelling as other mechanisms are possible. Fig. 2 gives a few examples of emission lines interpreted as the consequence of a shock propagating through the atmosphere. The case of Long Period Variables (LPV) is certainly the most famous example and will be analysed in the next section.

The RV Tauri stars are characterized by spectral types F, G or K; luminosity class Ib or Ia; and pulsation periods of 30 to 150 days with an amplitude of 3 magnitudes. The Hα profile of R Sct (Fig. 2a) has an inverted P Cygni profile with a red-side emission. A few double absorption lines and He I emission are also observed. This latter emission is important because it means that the shock has a large intensity, provided, of course, the shock produces this line. The shock wave "explanation" has been lately discussed for AC Her by Baird (1982).

The β Cephei stars have a spectral type B and a luminosity class II, III or IV. The period range is from 0.13 to 0.3 day and the amplitude up to 0.2. LeContel and Morel (1982) have observed a small emission component within Si II (see Fig. 2b) and Mg II in γ Peg, and Goldberg et al. (1974) have detected in the spectra of β Cep an asymmetric sharpening of the red wing of Hα. These emissions are interpreted by the propagation of a shock wave.

The δ Scuti stars or dwarf cepheids (see Breger, 1979, for a discussion of these names) have spectra between A and F; luminosity class between III and V; periods between 0.03 and 0.2 day, and amplitudes which do not exceed 0.8 magnitude. Dravins et al. (1977) have observed a very small emission (see Fig. 2c) within Ca II K absorption of ϱ Pup. The dashed reference profile is the average of the profiles from 30 plates. These authors explain this phenomenon by the propagation of a shock through the atmosphere.

Finally, the set of cepheids (classical cepheids, W Virginis stars and RR Lyrae) show also a few emission lines (see Figs. 2d to f). The two first groups are characterized by spectral types F to K with high luminosity class I a or II. The period range is from 1 to 50 days and amplitudes between 0.1 and 2 magnitudes. The spectral type of RR Lyrae is A or F and the luminosity class is III. Their amplitude is approximately the same but the period is shorter (0.2 to 1.2 days). The emission lines in W Virginis and RR Lyrae are also interpreted by the propagation of a shock through the atmosphere. However, the classical cepheid stars show only lines with a weak excitation potential (Ca II) and a shock explanation is also proposed (Hutchinson et al., 1975).

Thus, RV Taurus, W Virginis and RR Lyrae stars show clearly hydrogen emission interpreted by shock wave models. βCMa stars show also emission lines with high excitation potential but weaker. The shock wave interpretation has also been proposed. Only the classical Cepheids with the same pulsating amplitude as the W Virginis stars and the δ Scuti stars are without emission lines with high excitation potential such as hydrogen. The intensity of the shock is certainly smaller for these two last groups than for the other ones.

In general, within a gas, motion of matter with a velocity larger than the sound velocity $a_s \sim 11700 \sqrt{T_o}$, where T_o is the temperature of the unperturbed atmosphere, gives a shock wave (for $3{,}000 \lesssim T_o \lesssim 30{,}000$ K one has $5 \lesssim a_s \lesssim 20$ km/s). An upper limit of the temperature T_s just after the shock front is $T_s \lesssim 3\ 10^{-9}\ v_s^2$, i.e. the temperature of the de-excitation zone in the wake of the shock is very approximately 5 or 20 times smaller. Thus, a velocity of the order of 40 km/s will certainly be sufficient to produce the emission of hydrogen. How can a pulsating motion with a subsonic velocity produce a motion with a supersonic velocity? Is the pulsating motion at the origin of the shock wave or the shock wave at the origin of the pulsating motion? Is there an acceleration mechanism of the pulsating motion? When the matter is falling back from the previous cycle, can the shock be produced by the interaction of this matter with the advancing one from the next pulse or by its reflection on the dense stellar core?

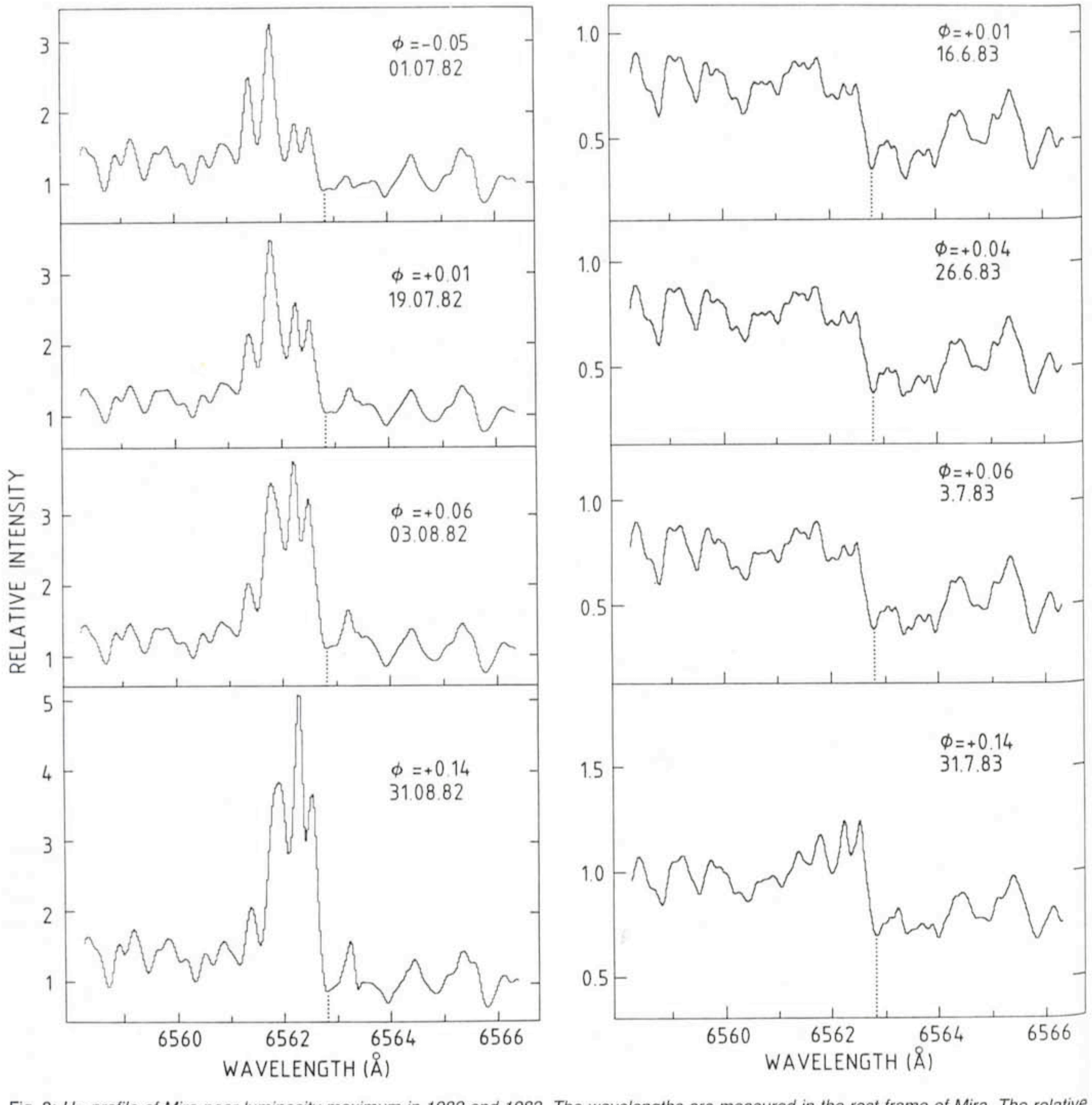


Fig. 3: *Hα profile of Mira near luminosity maximum in 1982 and 1983. The wavelengths are measured in the rest frame of Mira. The relative intensity refers to the mean level of the "continuum" between 6564 Å and 6572 Å. The wavelength of Hα at zero velocity in Mira's rest frame is marked by a dotted line. In this presentation the individual pixels are visible, each pixel being 30 m Å wide, corresponding to a resolving power of 10^5. The signal-to-noise ratio is between 300 to 500.*

The Shock of Mira Not on Schedule

The Long Period Variables are composed of three groups. The first two, semi-regular variables and irregular variable stars whose amplitudes do not exceed 2 magnitudes, do not present hydrogen emission lines. Only in a few cases are there some metallic emission lines present and these are perhaps the consequence of a chromosphere. Only Mira stars, the third group of LPV, have hydrogen and an important number of ions in emission during a large fraction of the period. Their amplitude is between 2 and 3 magnitudes. All these stars are of spectral type M, S or C and have luminosity class II or III. The period range is from 50 to 500 days and more than 1,000 days for a few semi-regulars.

The idea that one shock wave crosses the atmosphere at each period and produces the emission lines is well accepted. Thus the correlation between the pulsation period and the shock is assumed to be important. What is the exact origin of the shock? Since the beginning of this century a large number of studies have been based on the Mira stars, but there is no clear and quantitative answer to this last question. The velocity of the front is typically between 50 and 70 km/s, i.e., 10 or 15 times the sound velocity. How can a pulsation motion create a wave propagation to Mach 10 or 15?

Fig. 3 shows two sets of Hα emission profiles of Mira Ceti in 1982 and 1983 near luminosity maximum. All these spectra have been obtained with the Coudé Echelle Spectrometer of ESO. The resolution is about 60 m Å and the signal-to-noise ratio between 300 and 500. The shock seems weaker in 1983 than in 1982. The emission from the shock appears near phase $\Phi = 0.14$ in 1983 while the emission was already important at phase −0.05 in 1982, i.e., 63 days before the phase +0.14. Another explanation of this delay is that the shock has been created lower within the photosphere or also that the opacity of the latter shock was higher in 1983. The relative depth of absorption lines was lower in 1983 than in 1982. It is possible, perhaps, to understand this phenomenon by a lower luminosity of Mira in 1982 than in 1983. Finally, it is interesting to see that the three absorptions at approximately 6561.6 Å, 6562.0 Å and 6562.4 Å within the assumed emission profile at phase +0.14 have again not received a correct explanation. However, the first three profiles of Fig. 3, perhaps without emission, show five small absorptions.

Finally, these observations show that the phase of apparition of the Hα emission can be very different from one luminosity period to the next. This phenomenon is perhaps a consequence of the modification of the shock intensity and it may be that there is also a direct correlation between this fact and the slight variation of the period and amplitude (~ 5 %) of Mira stars. The 1983 profiles of Fig. 3 give perhaps the sequence of Hα emission caused by the shock.

Acknowledgements

We are grateful to Drs. D. Baade and R. Ferlet for their collaboration on the observations.

References

Baird, S. R., 1982, *P.A.S.P.* **94,** 850.
Breger, M., 1979, *P.A.S.P.* **91,** 5.
Dravins, D., Lind, J., Särg, K., 1977, *Astronomy and Astrophysics* **54,** 381 (c).
Dürbeck, H. W., Seitter, W. C., 1982, *Landolt-Börnstein,* **2,** p. 197, ed. K. Schaifers and H. H. Voigt, Springer-Verlag.
Goldberg, B. A., Walker, G. A. H., 1974, *Astronomy and Astrophysics* **32,** 355.
Havlen, R. J., 1970, ESO Annual Report (d).
Hutchinson, J. L., Hill, S. J., Lillie, C. F., 1975, *Astronomical Journal* **80,** 1044.
LeContel, J.-M., Morel, P.-J., 1982, *Astronomy and Astrophysics* **107,** 406 (b).
Preston, G. W., 1962, *Astrophysical Journal* **136,** 866 (a).
Preston, G. W., Paczynski, B., 1964, *Astrophysical Journal* **140,** 181 (f).
Wallerstein, G., 1959, *Astrophysical Journal* **130,** 560 (e).

Blizzard at La Silla

W. Bauersachs, ESO

In the beginning of July 1983, an unusual snowstorm somewhat perturbed the life on La Silla. Here are the records:

Thursday, July 7, 1983: bad weather with symptoms of a development to the worse.
Friday, July 8, 1983: snow-storm, power-failure, evacuation of the mountain, 30 trapped.
Saturday, July 9, 1983: storm continues until midnight.
Sunday, July 10, 1983: bright weather, snow-sweeping, repairs.
Monday, July 11, 1983: half of the crew returns, preparations of equipment.
Tuesday, July 12, 1983: return to full work.

Things like that always happen on Friday, a fact confirmed by long experience. Just when the majority of the people are anxious to leave the mountain and to see their families.

You imagine what it then means when the road is blocked by mud and landslides! This time the event was quite extraordinary, otherwise it would not be worthwile to write its story. We do have snow on La Silla, sometimes. We also do have strong winds, even very strong ones, from time to time. But both extremes together? May be some elder ones remember.

The symptoms were unequivocal: a high dark cloud stratification, a second one lower than the Observatory, squalls whip the fog upwards the valleys, temperature decreases. Fog envelopes first the ware-house, then the work-shops, the hotel and the dormitories and eventually the highest top with the 3.6 m telescope. Clouds rush from the north-east over the La Silla ridge. It is already rather uncomfortable outside. Rain turns to snow in the evening hours. This was on Thursday.

Next morning a little snow on the roads, vehicles are stuck, drivers are scratching ice from the panes. However, they do not get very far. But nobody is really apprehensive as yet. This will start only one hour later. Wind speed increases, snow fall is so intensive that the visibility is only a few meters. In a few places feverish activity develops in spite and because of the nasty weather: snow chains are prepared for the vehicles, equipment is covered with plastic foils for water protection, a car goes to Pelícano to inspect the road conditions, the porter there reports heavy rain fall.

Shall we now send the people down to La Serena? What becomes of the air-plane passengers? Who remains on the mountain? Lots of other questions! Here the decisions: the bus leaves at 11 o'clock taking also the air passengers to La Serena, from there they shall continue by ground transport, only a small emergency group of a dozen persons shall stay.

Suddenly the electric power supply of the whole Observatory fails. There is no possibility to locate the failure, a short circuit somewhere. We know only it is not in the new high tension line, but the rest is dead. The snow-storm prevents the access to the switching stations, so there is no means to isolate the defect. The snow-plough shall open a way! Sorry, it is since a long time busy on the road to Pelícano, far away.

From now on the characteristic events will be recorded as episodes, not quite in chronological order, but characteristic.

Shivering and soaked people gather in the dining-room waiting for transport to the car workshop from where the bus will leave to La Serena. Hundreds of questions! Especially by the visitors, astronomers, Garching staff. Some want to leave, others not. Can I leave my equipment behind? How is the road condition? Why does the telephone not work? How can I come to Santiago? Is there a bus from La Serena?

Wind velocities are registered on Friday morning up to about 120 km/h. But then nothing more. No electricity means no signal transmission and nobody thought of standing out in the horizontally drifting snow holding up an anemometre.

The passenger bus said to be ready to start is lacking gasoline. Also there is no electricity. Some mechanics work

Fig. 1: *The observatory seen from the 3.6 m telescope CAT-walk on Monday, July 11 (photo: S. D'Odorico).*

hard with icy fingers to make a transfer by hand from an emergency tank.

Power failure does, in general, not only mean no light, no telephone, but also no heating, no cooking, no water. Fortunately, we are prepared in some respect: a gas-stove in the kitchen and plenty of water reserve reaching consumers by gravity. However, congelation of the long line is imminent, but it will not happen, at least not to the main line.

Our snow-plough mounted on the Unimog is requested everywhere. But its work is rather hopeless. Nevertheless the road to Pelícano is passable. Who may be the disguised operator behind the frosted windows?

Fire brigade and technical emergency group people appear dressed in their green overalls and their yellow mackintoshes. This is the occasion to show the fancy outfit. Anyway, they are better protected than those wearing the traditional ESO parka.

Eventually the passengers leave by bus and other vehicles. Only hours later we know all arrived safe in La Serena. But the scheduled return of the bus is out of question for the Panamerican Highway is blocked by land-slides. About thirty are trapped at La Silla.

Kitchen staff reports there is plenty of food.

The mobile 40 kW emergency generator is towed up to the hotel. Muffled up electricians and mechanics are changing the cable connections with icy fingers and . . . the thing works fine. So there is light in the hotel again, the coffee machine works, the telephone and the radio functions. Some are already enjoying a warm lunch. What was it? Who remembers?

There is no telephone connection to La Serena and also not to Santiago; there, the nets broke down. But we do have our short-wave radio. The porter at the La Serena office reports the arrival of all passengers. Later, we reach also the Guesthouse in Santiago.

Eventually, we can get access to two electrical switching stations in the afternoon. Several tests, several failures, finally a limited success. The lower zone gets power: workshops, warehouse, dormitories and clubhouse and – most important – the heating station. For the rest, there is no hope for today. Please be aware, these few lines mean hard and most uncomfortable work for a couple of men during several hours in the blizzard.

The snow-storm continues, but the situation for the crew at La Silla is again fairly comfortable, as far as they have no outside business. There is even a cinema performance at night. After dinner we can supply also the upper zone dormitories with power from the emergency generator. Everybody is very disciplined by economizing electrical current.

Fig. 2: *The 3.6 m telescope photographed from the hotel building (photo: S. D'Odorico).*

Some visitors, who may be used to night work, are enjoying a noisy party with bursts of laughter until the early morning hours, although the poor guy next door is deadly tired after the unusual work.

Next day, Saturday, the same picture: storm, snow, frost. The brave crew of the snow-plough continues its rather hopeless battle. The snow limit is at our lower pump-station at about 1,500 m altitude. Our Caterpillar frontloader comes for relief. It can better handle big snow masses. Finally, the roads up to the new 2.2 m telescope are passable for cars with snow chains.

Our 4-wheel-drive vehicles proved to be extremely useful. A shuttle bus runs from the hotel to the telescope zone and to the lower dormitories.

Some visitors undertake expeditions in the snow, some even fight their way up to the 3.6 m telescope in order to save the clock or their computers. But the clock is almost dead, its reserve battery does not last so long. You can take it as a sport, then it may make fun, but if you take it as a duty, the picking snow crystals rushing at 100 km/h into your face are really no fun.

Since the visibility is a bit better today, we discover at least one reason for the power failure. Two wooden poles of the 6,000 V distribution line are broken by wind and snow load on the wires. There is no hope for repairing or isolating; but there must be more damages. The circuit breakers still refuse to be switched in.

The telephone connections are working again. There is an endless chain of calls by apprehensive families and deported astronomers, the latter asking if they can return for observations. No comment!

For lunch we have one of these typical Chilean bad weather dishes *sopaipillas* and *picarones*. The kitchen staff does its best.

We have to do something about the entertainment of the out-of-work visitors. Some must have seen the few video tapes a number of times.

After dinner a desperate call comes from the porter-house at Pelícano. We had nearly forgotten the lonely man down there, and now he is afraid of being drowned. *"Corre la quebrada":* this means that a stream of water is flowing down the valley. This, too, is a rare phenomenon, but we had it now three times after a dry period of many years. The porter is consoled by the advice to move to a somewhat higher place. Anyway, the Unimog drives down through night and snow, then rain. May be it can prevent water damages to the porter house by excavating some trenches, and so it does. During the hour-long return trip up-hill the two on their engine perceive that wind and snow are abating. Arriving at La Silla the most beautiful powdery snow is whirling in the head light beams.

Sunday morning is bright with sunshine and glittering snow. Visitors with cameras are seen all over the mountain.

Roads are now covered with ice, traffic is dangerous, but the snow sweeping progresses well and also the electricians succeed in connecting little by little the various zones after a careful cleaning of the switchboards from snow and ice. The main damage can be by-passed and the rest can be repaired on Monday.

In general, the snow is only 20 to 30 cm deep. It seems all was swept down-hill by the storm. But there are several snow-drifts more than 2 metres high.

About half of the staff arrives on Monday noon in order to check all equipment and to put it again in operation. At some telescopes, even the scientific night-work starts.

On Tuesday, the Observatory works again full power in spite of the traffic restrictions.

There are further damages, of course, to buildings, roads and equipment, but altogether of relatively low importance. It will take some time to get everything repaired.

As the wise men at La Silla predicted, there is now in September and October a consequence as rare as the above-mentioned events, manifesting itself by an intense carpet of flowers and grass all over the usually arid region.

ALGUNOS RESUMENES

El telescopio de 2,2 m se encuentra listo

El telescopio de 2,2 m de Zeiss es el último telescopio que ha llegado a La Silla gracias a un préstamo otorgado por la Sociedad Max Planck a la ESO por un período de 25 años, y en retribución la Sociedad Max Planck recibirá un 25 % del tiempo de observación. ESO tuvo la responsabilidad por la instalación del telescopio, por las modificaciones necesarias y la construcción del edificio y la cúpula de acuerdo a las especificaciones acordadas con la Sociedad Max Planck. ESO tendrá además la responsabilidad por la mantención y la operación del telescopio.

La instalación del telescopio comenzó el 15 de febrero de 1983 y como resultado de la excelente colaboración entre el calificado personal de Zeiss y MAN y los servicios de muchos técnicos de la ESO se obtuvo la "primera luz" en la noche del 22 de junio de 1983. Durante las siguientes semanas se usó el telescopio para el ajuste óptico, mecánico y electrónico. El término del mal tiempo de invierno hizo posible comenzar a usar el telescopio con la cámara fotográfica, el espectrógrafo B & C con la cámara CCD, o con un detector danés RPCS y la cámara CCD en modo fotográfico. En su mayor parte la visibilidad fue superior a 1 arco por segundo, y aparentemente todos los instrumentos trabajaron al esperado nivel. En las páginas 15 y 16 de esta edición del Mensajero se encuentran ilustradas dos fotografías tomadas con el telescopio.

Actualmente se están haciendo los ajustes finales y existe justa razón para pensar que, como previsto, el telescopio será totalmente operable desde el 1° de enero de 1984, y que a partir de entonces los astrónomos europeos tendrán la ventaja de usar este potente nuevo telescopio en Chile. *M. Tarenghi*

Temporal de nieve en La Silla

A comienzos de julio de 1983 un temporal de nieve poco usual trajo algo de confusión a la vida en La Silla. El mal tiempo comenzó el día jueves 7 de julio con neblina, fuertes vientos y lluvia, la cual se convirtió en nieve al anochecer.

El día viernes por la mañana la montaña se encontraba cubierta por una capa de nieve. Pero ésto fue tan sólo el comienzo. La nieve cayó mas copiosamente, la velocidad del viento aumentó a aproximadamente 120 km por hora y la visibilidad se redujo a sólo unos cuantos metros. Para empeorar aun más la situación, la energía eléctrica falló en el observatorio. El barrenieves ya estaba en camino a Pelícano por lo que no hubo modo de abrirse camino a las plantas de energía para poder subsanar el defecto.

Ya que un fallo de energía eléctrica no sólo significa que no haya luz ni teléfono, sino también fallan la calefacción y la cocina, se decidió enviar al personal y a los visitantes en bus a La Serena y de sólo conservar un pequeño grupo de emergencia en la montaña.

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

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

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

The text of any article may be reprinted if credit is given to ESO. Copies of most illustrations are available to editors without charge.

Editor: Philippe Véron
Technical editor: Kurt Kjär

EUROPEAN
SOUTHERN OBSERVATORY
Karl-Schwarzschild-Str. 2
D-8046 Garching b. München
Fed. Rep. of Germany
Tel. (089) 32006-0
Telex 5-28282-0 eo d

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

ISSN 0722-6691

El generador de emergencia móvil de 40 kW fue remolcado al hotel. Arropados electricistas y mecánicos hicieron las conexiones necesarias con dedos tiesos por el hielo, pero finalmente todo funcionó. Por fin había luz en el hotel; el teléfono, la máquina del café y la radio funcionaban nuevamente. Aun no había contacto telefónico ni con La Serena ni con Santiago; la red estaba interrumpida. Pero funcionaba la radio de onda corta y la oficina de La Serena informaba que el bus con los pasajeros había llegado, pero que éste no podía volver a La Silla debido a que la Carretera Panamericana se encontraba interrumpida por deslices de tierra.

Más tarde fue posible llegar a las dos plantas eléctricas y después de un difícil y penoso trabajo en medio de la tormenta, la zona baja del observatorio, talleres, bodega, dormitorios, y lo mas importante, la estación de calefacción, obtuvieron energía eléctrica nuevamente.

La tormenta de nieve continuaba, pero la situación para el grupo en La Silla se presentaba más aceptable, es decir, para aquellos que no tenían que trabajar a la intemperie. En la noche incluso hubo cine. Después de comida también fue posible dar la luz en los dormitorios que se encuentran más arriba, todo ésto gracias al generador de emergencia.

Al próximo día, sábado, el tiempo continuaba igual: tormenta, nieve y hielo. El valiente grupo del barrenieves continuaba con su casi imposible batalla, mas finalmente el camino al nuevo telescopio de 2,2 m quedó transitable para vehículos con cadenas. Los vehículos de ESO con tracción a cuatro ruedas demostraron su gran utilidad. Un bus transitaba entre el hotel, el telescopio, y los dormitorios que se encuentran más abajo.

Después de comida se recibió una desesperada llamada de la portería en Pelícano. El pobre hombre allá abajo había sido totalmente olvidado. Un torrente bajaba por la quebrada y tenía pánico de ser arrastrado. El único consejo que podía dársele era de ubicarse en un lugar más alto. Sin embargo, a pesar de todo, el Unimog fue envíado hacia Pelícano en medio de la noche y la nieve que más abajo era lluvia. Se cavaron zanjas para evitar mayores daños a la portería.

El domingo por la mañana amaneció con sol, la nieve brillaba, y los visitantes sacaban fotografías de este extraordinario escenario. Dos de estas fotografías se encuentran ilustradas en la página 42 de la presente edición.

El día lunes regresó al observatorio aproximadamente la mitad del personal y el día martes, 12 de julio, todo se encontraba en pleno funcionamiento nuevamente, a pesar de las restricciones del tráfico.

W. Bauersachs

Contents